november 1957

metal progress

Metal Progress

Volume 72, No. 5

November . . . 1957

Cover by PATRICIA A. MCDONALD, a prizewinner in the annual *Metal Progress* Cover Competition at Cleveland Institute of Art

Engineering Articles

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**The coding symbols refer to the ASM-SLA Metallurgical Literature Classification, International (Second) Edition, 1957*

How you benefit from Electro-Alloys'

ENLARGED MACHINING AND CLEANING ROOM FACILITIES

Thermalloy high-alloy castings* are being produced in greater variety, size and quantity than ever before. To meet the increasing demands of our customers, new and enlarged machine shop and cleaning room facilities have recently been installed.

What does this mean to you? It means we can handle more and varied jobs faster. We can machine large castings to your specifications on the most modern type of equipment . . . lathes, shapers, milling machines, key seaters, drill presses, planers, grinders.

Our new cleaning room addition includes Wheelabrator, tumbling machine, abrasive cutoff machines, grinders, welding booths and casting storage. It is serviced by a crane to facilitate handling of large castings.

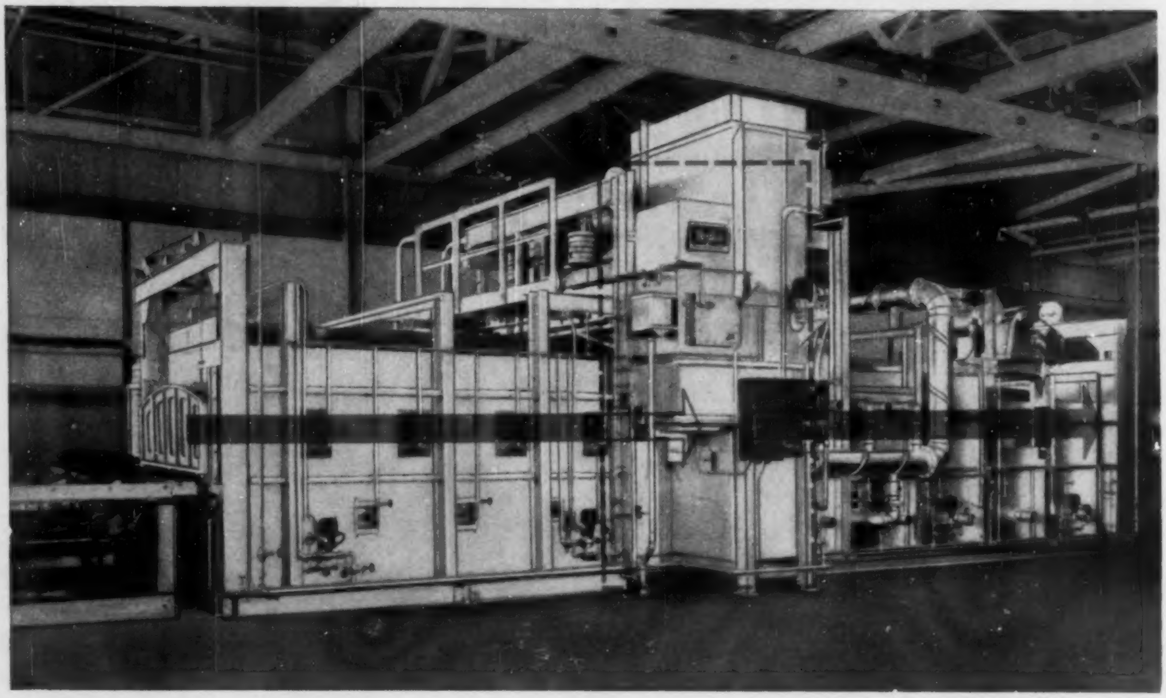
Why not take advantage of these enlarged, modern facilities on your next high alloy casting job? Call your nearest Electro-Alloys representative, or write us direct for information and quotes. Electro-Alloys Division, 80311 Taylor Street, Elyria, Ohio.

*Reg. U.S. Pat. Off.

AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION Elyria, Ohio

Superfast cooling for cycle annealing



A furnace-within-a-furnace makes this Surface cycle annealer one of the most versatile heat treat units in the country. It anneals, cycle anneals, and normalizes gear forgings of different size, shape, and alloy at the net rate of 864,000 lbs. per month or better.

Such exceptional versatility is achieved by a superfast cooling zone. Really a full convection furnace within a direct-fired furnace, this zone is isolated by refractory doors. It can be used or by-passed, depending on which of many cycles the customer wants. As a result, the customer can heat treat as many as 13 different alloys in this one furnace.

Adding to the flexibility of the furnace is a modular tray design. Each module is an 18x20-inch chrome alloy casting. Modules can be combined to hold any size of work up to 800 pounds. They are also used to carry work outside the furnace.

This furnace-within-a-furnace is another proof that Surface engineers are old hands at creating new ideas in heat treating.

Write for Bulletin SC-146 on cycle annealing.

Surface Combustion Corporation, 2377 Dorr St., Toledo 1, Ohio. In Canada: Surface Industrial Furnaces, Ltd., Toronto, Ontario.

wherever heat is used in industry

Surface

As I was saying...

Everything works out well if you are patient and persevering. Now I recognize that the above should be in quotes but I cannot remember to whom to attribute it. But anyway the A.S.M. Board has been patient and has been keeping right at it to secure from the architect a headquarters design that would be appropriate for the Society – would be original in its concept as a building for a metal society – that would be distinctive, efficient and functional, and would be a source of pride for the 29,000 members.

We worked for over a year with an out-of-town architectural firm and studied some nine projects but could not accept any submitted, not only because all exceeded the budget ($1,500,000) but they never seemed to be "The Building" we had in mind. So we found it necessary to seek another source for inspiration and design.

It was only a few weeks before our patience was rewarded, and like manna from heaven, there came into our lives John Terence Kelly of the firm of Kelly and Kress and Associates of Cleveland. Mr. Kelly is a young architect, full of pep and vision, with excellent training and with capable assistants, who on his first presentation came up with a design that passed the Board Committee (Young, Lorig, Eisenman) and also received the unanimous approval of the entire A.S.M. Board of Trustees.

The Board selected Gillmore-Olson Co. (of Cleveland) to be the contractor and builder.

The Master Plan has been approved, the Zoning Board of Russell Township (in which the headquarters building is located) has given unanimous approval, surveys have been made, a well is being drilled, and the road leading to the (*Continued on p.* 6)

Messrs. Eisenman and Kelly Examining a Visualization or Diagram of the Main Lines of the New A.S.M. Headquarters' Structure

site will have its foundation placed this fall so the heavy construction loads can be hauled when spring comes. It will require about 11 months from about March 15 or April 1 for completion.

I want to give you a brief on John Kelly's training. I know you will recognize by his training and travels that he is the "manna from heaven" who has the responsibility of placing the A.S.M. headquarters in a beautiful garden setting.

John Terence Kelly received the B.A. degree from Carnegie Institute of Technology, the M.A. in Architecture from Harvard under Walter Gropius, and the M.A. in Landscape Architecture from Harvard under Hideo Sasaki. In addition he has studied painting, sculpture, and the history of civilization at the Universities of Biarritz and Grenoble. Among honors he has received are the Charles Eliot Norton Traveling Fellowship from Harvard and a Fullbright Grant to study City Planning in Munich, Germany.

Mr. Kelly has had diversified experience with a number of well-known architectural firms. In Cleveland he worked with the firms of Outcalt, Guenther & Associates and Ward & Conrad. In Boston, with the office of George W. W. Brewster, he designed in 1953 the *House and Garden* "House of Ideas", and in 1954 the J. Gordon Gibbs residence which was recognized by the Boston Arts Festival as the best in New England. His partnership with James Nessly Porter produced the "House of the Year", an award by *Progressive Architecture* magazine. From the above you can judge for yourself. It's good news I bring to you and I know you are as happy as we are.

The A.S.M. of Tomorrow has been on its way for some time. The Metals Engineering Institute is now in action with more than 300 students enrolled in the first three months; the advertising campaign will start at the first of the year. The Metallurgical Seminars are in progress and soon the cornerstone of the first unit of the building program will be in full swing. It'll be a great day for all of the A.S.M. when it breaks ground for the first time and begins an era of greater progress for the Wonderful World of Metals.

Cordially,

Bill

W. H. EISENMAN, *Secretary*
AMERICAN SOCIETY FOR METALS


Cooper Alloy
eliminates
excessive
distortion
of jet
aircraft
rings—
with
GULF SUPER-QUENCH

New trends and developments for design engineers . . .

How Carboloy® cemented carbides' wear-resistance and other unique properties solved three tricky problems

Carbides' low coefficient of thermal expansion keeps tiny parts tiny

The Van Keuren Co., Watertown, Mass., specializes in precision measuring tools, and tiny parts such as bearings and pivots for instruments, components, and missiles.

Dimensions of these parts are often measured in thousandths . . . and their tolerances in millionths.

It's hard enough to *make* anything as small as the pivot shown in Figure 1, but once it's done, making sure it *stays* that size despite ambient temperatures and rugged operating conditions is another problem.

FIG. 1 — Carbide pivots measure .0030" in diameter, .0165" in length.

Carboloy cemented carbides were the perfect solution because they do not expand and contract like other materials. Their coefficient of thermal expansion is less than half that of SAE 1095 heat-treated steel.

For example, from 70° to 1292°F., Carboloy Grade 779 has a coefficient of $2.80 \times 10^{-6}/°F.$ – compared to $8.20 \times 10^{-6}/°F.$ for SAE 1095.

In addition, carbides resist atmospheric corrosion and erosion. They can be lapped and polished to a mirror finish for smooth, accurate bearing action. And they're ideal materials where compressive loads are high because carbides' ultimate limit in compression is 2 to 16 times that of steel.

Carbides' high temperature resistance solves soldering problem for H. & A. Selmer

Soldering clarinet keys in place takes a steady hand with the gas torch, and special jigs for holding and positioning tiny assemblies (Figure 2).

H. & A. Selmer, Inc., leading manufacturer of band instruments had no trouble getting the steady hands. The problem was with the jigs.

FIG. 2 — Carbide points hold and position clarinet key assembly during soldering.

Because of the high temperatures needed for silver soldering the nickel-silver keys, Selmer was using stainless steel jigs. Unfortunately, the keys often ended up soldered to the jig; as well as to their own parts. This meant hours of hand filing, extra cleaning, frequent repairs of the jigs.

Then Selmer engineers introduced the use of Carboloy cemented carbide location points. In addition to being the hardest metals made by man, they have the ability to resist excessive oxidation at temperatures of 1500° to 1600° F.

And, once carbide is coated with a thin layer of oxide, neither the solder, nor the keys, will stick to the holding and location points.

Soldering operations were speeded up; hand filing eliminated; jigs stayed accurate longer—and Selmer's costs came tumbling down.

Carbide's resistance to corrosion keeps printing ink flowing for IBM

When IBM makes IBM cards, it makes them by the millions. And it makes them on special high-speed machines that automatically print, cut, and count 1600 cards a minute.

Each machine has its own miniature printing press. Ink is metered out by a stainless steel pump submerged in a well in the machine base.

Wear on the pump parts was problem enough. But the ink was also corroding its impeller bushings and shaft.

IBM engineers solved the problem by installing Carboloy cemented carbide bushings and shafts.

Normally, carbides are not used for their corrosion resistance alone.

But, as in cases like this, where a *combination* of corrosion-resistance and wear-resistance is needed, Carboloy cemented carbides can more than pay their own way.

They have good resistance to organic acids, many inorganic acids and bases . . . and are practically inert to attack by salt water spray.

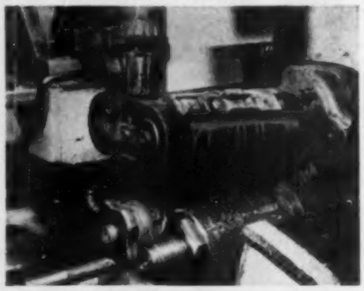


FIG. 3 — Miniature printing press in IBM card machine. Note carbide shearing knives above the printing plate.

Incidentally, IBM is also saving an estimated $40,000 a year in labor costs for regrinding the rotary shear knives used to cut the cards to length.

By changing to Carboloy carbide knives, 267 million cards are trimmed before resharpening — compared to only 16 million with steel knives.

IBM, Selmer, and Van Keuren each used a *different* grade of carbide. Because Carboloy carbides are available in 19 standard grades, they could select the grade with exactly the right characteristics for their particular needs.

If you would like additional technical data on the unique properties of this material—or expert assistance on design problems, write: *Metallurgical Products Department of General Electric Company, 11167 E. 8 Mile Road, Detroit 32, Michigan.*

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CEMENTED CARBIDES
GENERAL ELECTRIC

Dallas Metal Show has been added –

to your Sales Territory . . .

The great Southwest – the industrial Southwest–rich, growing, bustling – is waiting for you. Here's a new sales territory that means profits for modern-day pioneers.

There'll be thousands of *new* prospective customers who'll crowd the Southwestern Metal Show – to see your company's display – to hear your company's story – to buy your company's product.

Over two million people live and work within a day's drive of Dallas. They are your prospects, interested in all that's new and improved. This is a chance you can't afford to miss.

Mark those five days next May as the "Days that Pay". You'll find them just that, because thousands will be at the Dallas Metal Show, searching for production advantages that will help improve operations, services, products – and at lower costs.

These prospects will be ready to buy. They'll be "preconditioned" – for the great Southwest is on the march, sparking sales to improve its own business economy.

ASM Metal Shows are famous as sales stimulants. They are "musts" for any firm with an eye on an expanded tomorrow. Here in the Southwestern Metal Show is a rich metal market full of opportunity for the prospecting manufacturer. Here's a show that will out-draw, out-sell and surpass anything you've experienced before in the "great open spaces."

STATE FAIR PARK

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MAY 12-16, 1958

Because the Show is staged in Dallas' spacious State Fair Park, only two miles from the city's center and downtown hotels, you'll be able to put your best foot forward before a top level audience looking for just what you've got to offer. There never was a finer exhibition hall – all on one level – airy, bright. It puts visitors in the right frame of mind to buy. It will be bristling with ideas and thronged with buyers.

Get your share of this new market. The Southwestern Metal Show is the place to sell! Act today – select your space. If you don't have floor plans, write us NOW. You'll reap a harvest from this new and finer Metal Show. To assure success in '58 – Don't Hesitate!

Southwestern Metal Exposition

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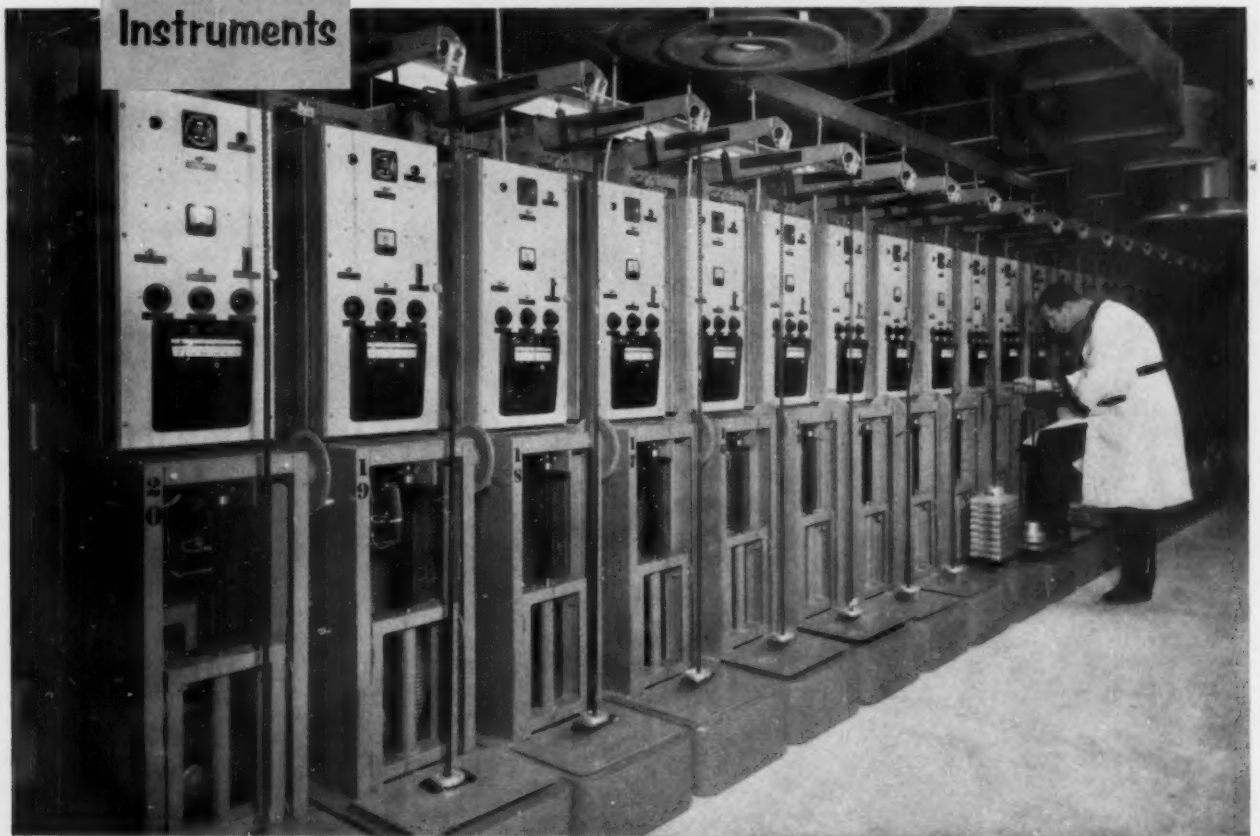
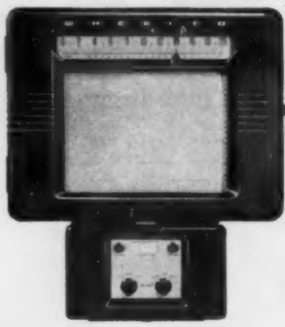
State Fair Park Is Only Two Miles from Downtown Hotels

METAL SHOWS OWNED AND OPERATED BY THE AMERICAN SOCIETY FOR METALS





Instrument standardization shows results in outstanding performance at Joliet Metallurgical Laboratories

It's Wheelco — all the way — in this modern testing installation at Joliet Metallurgical Laboratories, Inc., Joliet, Illinois. Outstanding performance on creep and stress-rupture tests depends in large measure on the proper application of modern instrument standardization in terms of temperature control.

To achieve this outstanding temperature regulation — well within ASTM specifications — Joliet Metallurgical Laboratories chose Wheelco 407 saturable-reactor Capacitrols for use on their Arcweld creep-test machines. Materials tested range from alloys of magnesium, aluminum, and titanium, through the stainless steels to the superalloys — a temperature span from approximately 400° to 2200° F.

Why did an organization with high-performance requirements standardize on Wheelco in this test battery? High degree of accuracy and reproducibility are the leading reasons — but low initial cost and an impressive maintenance record are extremely important in the decision.

In a test setup like this one, just as in numerous other installations, Wheelco's famous plug-in chassis eliminates countless maintenance headaches. That's why it pays to standardize on Wheelco Instruments. A spare chassis — prechecked and ready to go — can be inserted and the malfunctioning unit taken to the shop for checking under ideal conditions.

You'll find more advanced design features in Wheelco Instruments than in conventional units that only look similar. Your broadly experienced Wheelco field engineer will help you survey your instrument needs and point out where your processing can be improved materially with the proper instrumentation.

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FROM WHEELCO...

Capacitrols — companion to the 400 Series featured above are these horizontal "Panel-mount" types. Both styles are available in a variety of control forms: time-proportioning, two-position, Multronic, proportional-position, and electrical-proportioning.

Indicating Pyrometers — built to highest standards for precision instruments . . . feature meter movement with Alnico V magnet and electrical compensators for resistance changes in the metering system.

Packaged Control Centers — rewired, prefabricated Wheelco control provide major savings by simplifying installation and incorporating instruments and accessories in a single unit. Instruments shown here plus any others in the complete Wheelco line can be combined in a single attractive and efficient unit.

The Quench That's Different . . . Because It Has Safety Factor

There's one *sure* way to get the hardness your heat treating practice prescribes . . . use HOUGHTO-QUENCH Oil.

You get the benefit of a safety factor with HOUGHTO-QUENCH, because it's the fastest quench this side of water. It is extremely stable, will not break down. It has a high flash point. It wets out fast and drains off work fast.

There is so little sludge formed in HOUGHTO-QUENCH that many heat treaters are today using HOUGHTO-QUENCH that was installed before World War II.

Get the details from the HOUGHTON MAN who calls on you.

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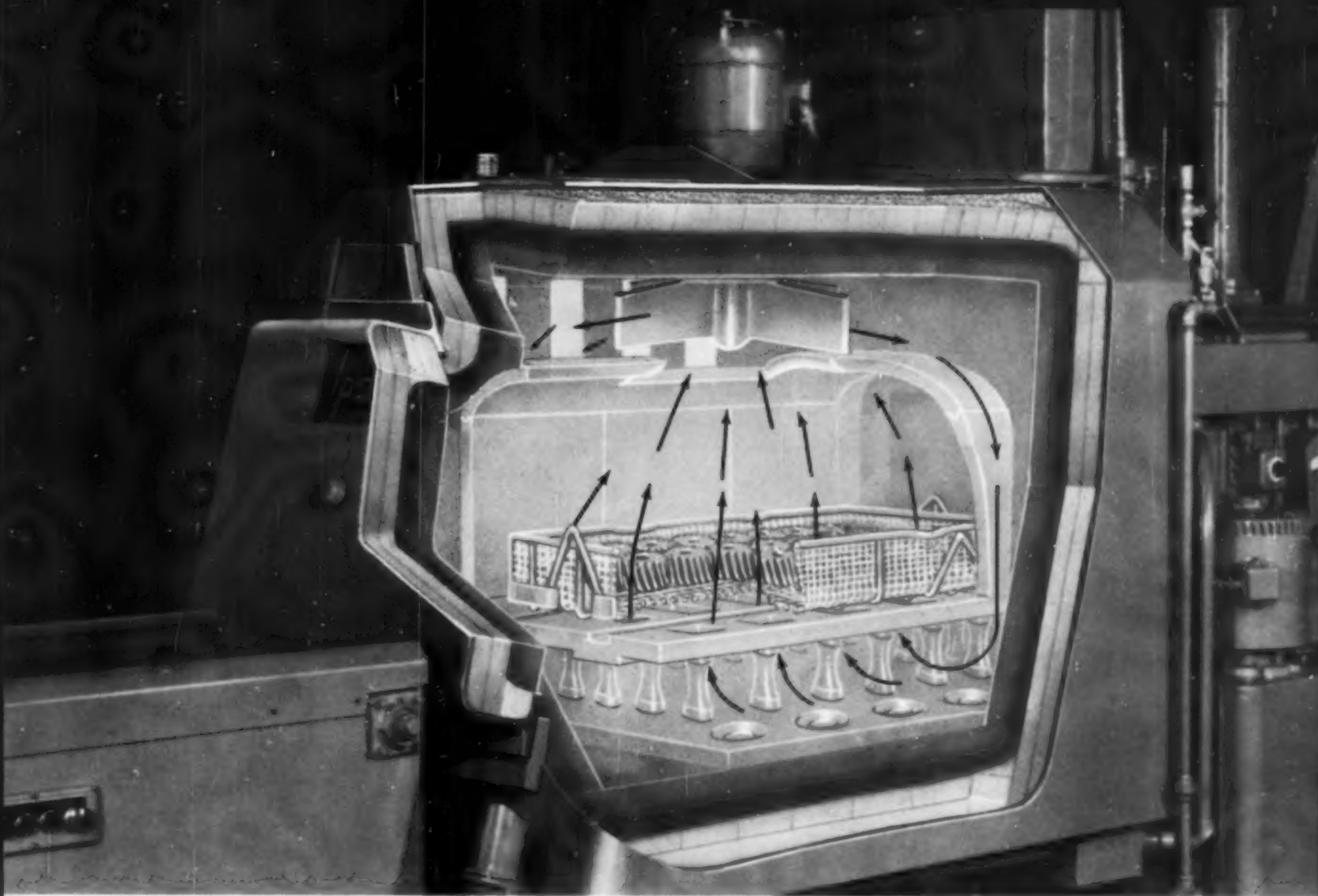
Ready to give you on-the-job service . . .



Superior controlled atmosphere heat treating

. . . with Ipsen 100% forced convection

100% forced convection heating and exclusive alloyed ceramic heating tubes have been successfully combined in all Ipsen furnaces for special atmosphere carburizing, carbo-nitriding, heat treating, brazing or sintering, and other applications calling for temperatures up to 2500° F.

Here's what happens when a cold charge goes into an Ipsen furnace. Stored heat from the furnace walls is forced into the heating chamber to the work being heated. This causes the furnace temperature to fall until the furnace wall, the heating chamber, and the charge all reach the same temperature. Then the high velocity heat which is carried to every part of the heating chamber and the charge simultaneously raises the temperature of both the heating chamber and charge back to the desired control temperature.

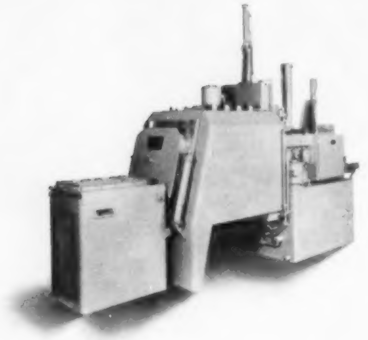
100% forced convection heating insures *uniform heating of every part of the charge* . . . whether it's loosely or densely packed. Both light and heavy sections are uniformly heated.

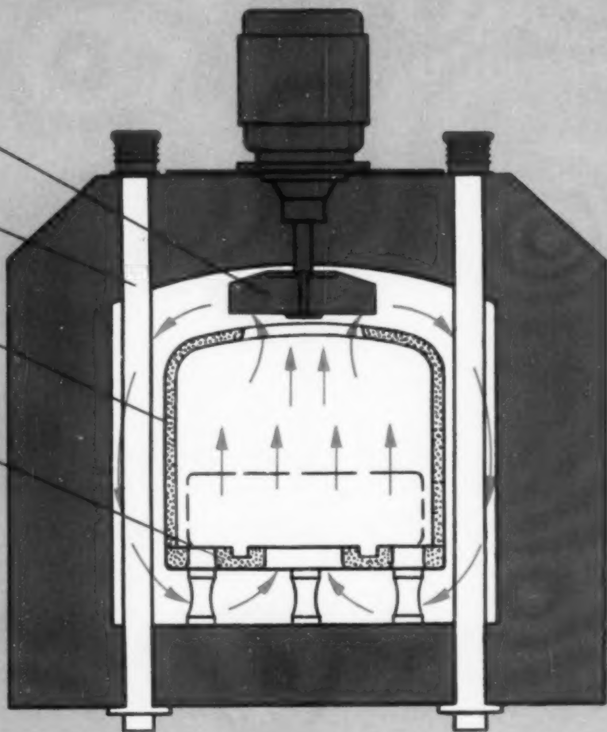
Ask for literature describing Ipsen 100% forced convection furnaces.

AUTOMATIC Ipsen HEAT TREATING UNITS

following page shows 100% forced convection chart

how Ipsen 100% forced convection works . . .





This centrifugal roof fan, powered by a husky, slow-starting motor, circulates the protective atmosphere . . .

down past these vertical alloyed ceramic heating tubes . . .

which are isolated from the work chamber by this baffle . . .

to the bottom of the furnace and then up through this heavy, open grid-hearth . . .

to all parts of the charge where correct working temperature is maintained.

Work is brought to heat uniformly . . . controlled atmosphere is forced to all parts of the charge.

Write for technical brochures describing Ipsen 100% forced convection furnaces.

AUTOMATIC Ipsen HEAT TREATING UNITS

IPSEN INDUSTRIES, INC. • 723 S. MAIN STREET • ROCKFORD, ILLINOIS

Columbia Tool Steels for 1957-58
with A.I.S.I. Identification and Type Classification of Tool Steels

GRADE	Type	C	Mn	Si	Cr	Ni	V	W	Mo	Co	Cb
		Identifying Elements, In Per Cent									
COLD WORK TOOL STEELS — OIL HARDENING — TYPE SYMBOL O											
EXLDIE	O1	.90	1.00	—	.50	—	—	.50	—	—	—
GM-02DIE	O2	.90	1.60	—	—	—	—	—	—	—	—
	O7	1.20	—	—	.75	—	—	1.75	—	—	—
MEDIUM ALLOY AIR HARDENING — TYPE SYMBOL A											
E-Z-DIE SMOOTHCUT†	A2	1.00	—	—	5.00	—	—	—	1.00	—	—
	A4	1.00	2.00	—	1.00	—	—	—	1.00	—	—
	A5	1.00	3.00	—	1.00	—	—	—	1.00	—	—
	A6	.70	2.00	—	1.00	—	—	—	1.00	—	—
HIGH CARBON-HIGH CHROMIUM — TYPE SYMBOL D											
	D1	1.00	—	—	12.00	—	—	—	1.00	—	—
ATMODIE	D2	1.50	—	—	12.00	—	*	—	1.00	—	—
ATMODIE SMOOTHCUT	D2	1.50	—	—	12.00	—	*	—	1.00	—	—
SUPERDIE	D3	2.25	—	—	12.00	—	—	—	—	—	—
	D4	2.25	—	—	12.00	—	—	—	1.00	—	—
	D5	1.50	—	—	12.00	—	—	—	1.00	3.00	—
	D6	2.25	—	1.00	12.00	—	—	1.00	—	—	—
	D7	2.35	—	—	12.00	—	4.00	—	1.00	—	—

†With smooth cutting free machining additives

*Atmodie and Atmodie Smoothcut contain approx V.90%

Second of a Series of Six Charts Covering A.I.S.I. Tool Steel Type Classifications

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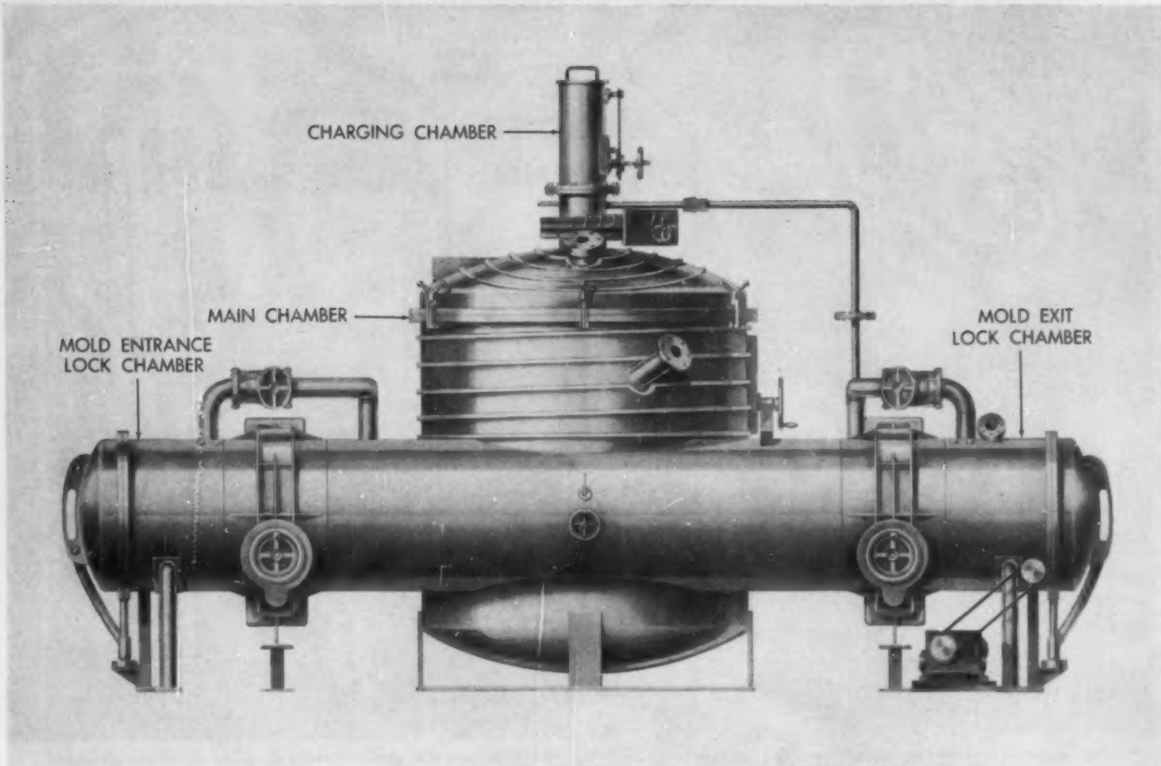
VACUUM



The Vacuum Melting and Casting Furnace shown above, as exhibited in the KINNEY Booth at the combined *Metals Show in Chicago*. This pilot plant or small production unit, designed for continuous operation, will melt up to 300 lbs. of Steel . . . (Zirconium, 250 lbs., Uranium, 725 lbs. and Titanium, 165 lbs.), forming small ingots or direct shape castings under high vacuum or inert gas atmosphere. The unit has many interesting features and great versatility.

The KINNEY Melting and Casting Furnace is composed of four basic sections which function as separate Vacuum chambers: 1—THE REMOVABLE CHARGING CHAMBER; 2—THE MAIN VERTICAL FURNACE CHAMBER, which contains the induction melting coil and crucible assembly with external mechanism for tilt pouring; 3—THE MOLD ENTRANCE LOCK arranged for isolation from atmosphere or main chamber; 4—THE MOLD EXIT LOCK for delivering the finished piece without breaking vacuum. Thus, 3 operations may be performed simultaneously—charging, melting and delivery of a finished mold.

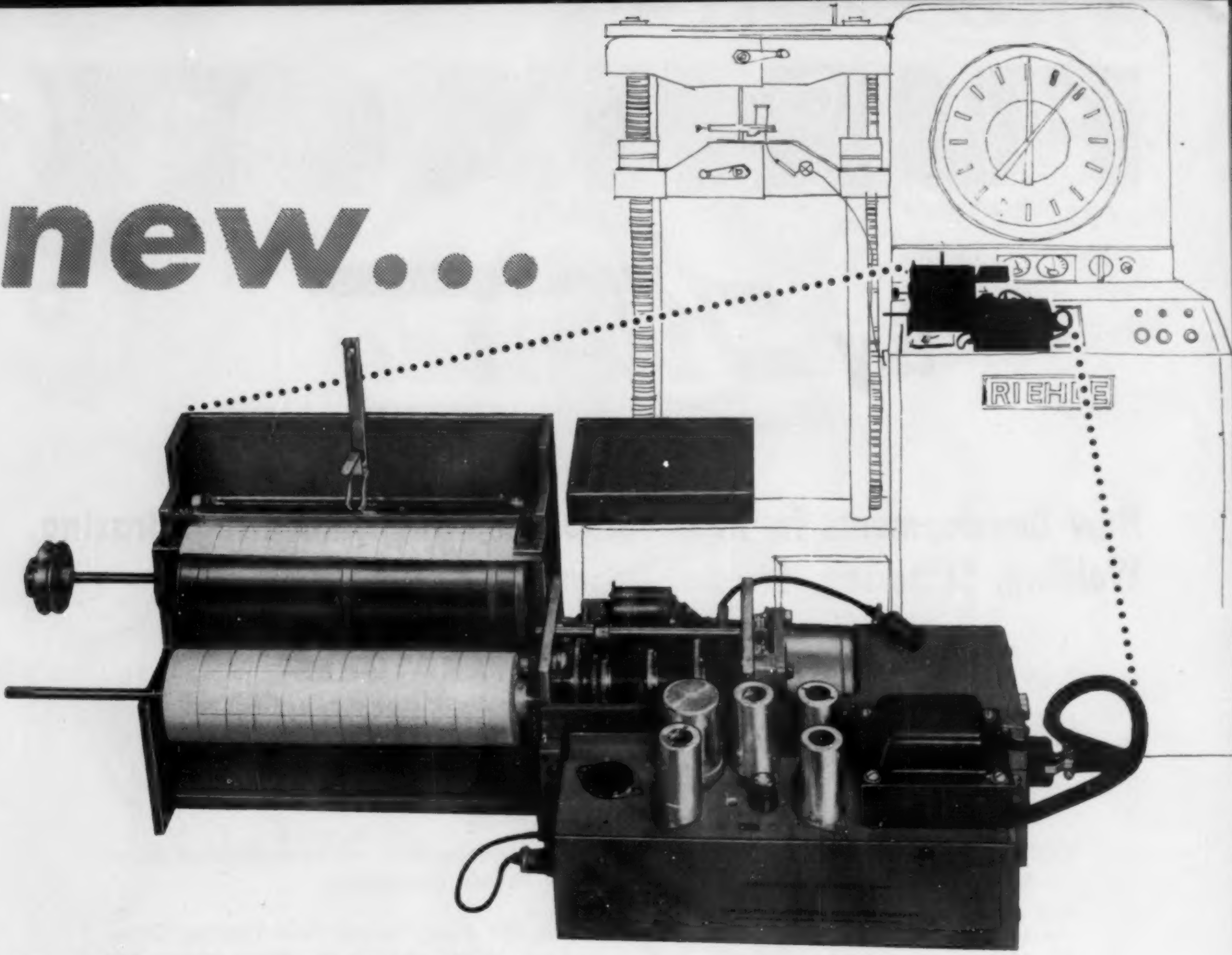
Modifications for power requirements and vacuum pumping facilities to precisely meet a special need are readily effected. Chambers and mechanism for addition of separate alloys may be added.

Furnaces of the same general principle may be supplied for capacities of 2500 lbs., 5000 lbs. or more. In these larger furnaces, valves, hoists and crucible tilt mechanisms will be equipped with air operated motors for infinite speed control instead of manual operation as in the unit shown.

IN OPERATION AT THE SHOW

Twice each day, visitors to the KINNEY Booth were given the opportunity of seeing a Sintering Furnace in actual operation. The KINNEY F-15 Sintering Furnace shown at the Metals Show is capable of working at 2200° C.

new...



Built-in RIEHLE recorder...

allows command post testing

See how the new recorder is built right into the Riehle indicating unit at a convenient location. That's why the operator can observe everything *from one spot* while a test is in progress. Without changing his position, he can watch the stress-strain curve . . . the load indicating dial . . . the strain and load rate indicators . . . and the test specimen. That's command-post testing!

Here is true convenience, because the Riehle recorder is expressly designed to function as an integral part of the Riehle testing machine. And a complete variety of Riehle strain follower instruments as well as special instrumentation for elevated temperature testing can be accommodated.

Free Bulletin . . . Mail Coupon

RIEHLE TESTING MACHINES
Division of American Machine and Metals, Inc.
Dept. MP-1157, East Moline, Illinois

Please send your big new Bulletin with full data on the Riehle Model RD-5 Recorder and special instrumentation.

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ATTENTION MR.

Riehle TESTING MACHINES

A DIVISION OF

American Machine and Metals, Inc.

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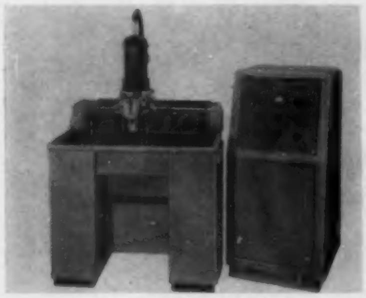
"One test is worth a thousand expert opinions"

APPLICATION and EQUIPMENT new products

X-Ray Microscope

A new projection microradiograph has been announced by the Instruments Div., Philips Electronics, Inc. The unit employs an X-ray source approximately one micron in size to produce enlarged images of specimens placed close to the radiating surface. Contrast is controlled to some extent by varying the accelerating potential of the electron beam and by changing target materials. The electron-optical system includes an electron gun, high-voltage source for electron accelera-



tion, electro-magnetic lenses to control beam size and configuration, and targets having surface planes normal to the beam at the end of its path. Images are observed on a viewing screen and are recorded with a camera that accommodates five exposures on a 2 by 10 in. plate. Exposure time is approximately 1 min. at 10 to 12 kv. Resolution is 1.0 micron or better at 2 to 20 kv. Direct magnifications up to 70× are possible on the photographic plate and up to 250× on the viewing screen-binocular combination. Total useful photographic enlargement is 1500×.

For further information circle No. 1340 on literature request card, page 48-B.

Tubing

A new line of conduit and electrical metallic tubing made of Yoloy, nickel-copper, openhearth steel, has been announced by Youngstown Sheet and Tube Co. Soil corrosion studies covering 14 years in 13 different soils show Yoloy pipe has 19% less pitting and 36% less loss of weight than carbon steel pipe, and 10% less pitting and 28% less loss of weight than wrought iron pipe.

For further information circle No. 1341 on literature request card, page 48-B.

Laboratory Furnace

R. Y. Ferner Co. has announced a Chevenard-Joumier laboratory furnace. It is a cylindrical bench-type unit which is automatically controlled to maintain a selected temperature or follow a pre-selected program heating cycle. Two types are available—one with a range to 1922° F., the other to 2372° F.

For further information circle No. 1342 on literature request card, page 48-B.

Aluminizing

A new control and heating station for preheating and diffusing automotive valves during aluminizing operations has been announced by Lindberg Engineering Co. The unit consists of a motor generator, a control station for regulating and controlling the application of high-frequency power and two heating stations. A vertical conveyor system wrapped around the 14-ft. high cabinet moves

the valves through the various operations and is loaded and unloaded automatically from the shop overhead conveyor. A metallizing gun with separate control panel sprays the valves with molten aluminum which in the subsequent heating operation forms an iron-aluminum alloy.

For further information circle No. 1343 on literature request card, page 48-B.

Sawing Graphite

National Carbon Co. has announced a band saw which will slice a 2-in. slab of graphite from a cylinder 45 in.

in diameter to an accuracy of ±1/16 in. It can cut material as thick as 49 in. and has a maximum table travel of 11 ft. A special blade is used to give the tolerances required. The plates being sawed in the illustration from a piece of graphite 35 by 110 in. will later be used for reference forms for the brazing of stainless steel honeycomb aircraft panels.

For further information circle No. 1344 on literature request card, page 48-B.

Pressure Chamber

A test unit that provides pressures to 30,000 atmospheres in a chamber ½ in. in diameter by 10 in. high has been announced by Nucor Research, Inc. Pressure is obtained by means of a 3½ in. diameter piston which is actuated by oil from a pump and which, in turn, actuates a ½-in. diameter piston in the top of the pressure chamber. The pressure chamber is inside a tube that has an external taper. As the chamber is brought up to pressure, a piston at the bottom of the Parabar is operated to force the chamber tube upward into a surrounding taper in a stack of heavy steel rings, thus applying a squeeze that prevents radial expansion of the chamber. Electrically-insulated leads


IN CUTLERY, TOO,
Sharonsteel Quality STANDS OUT
Cutlery manufacturers know well the name SHARON, for in the past five decades SHARON has excelled in the production of steels used in the manufacture of implements for cutting.
From exquisite carving blades to rugged chain saw teeth, razor sharp scalpels, agricultural and earth moving equipment SHARON provides the edge holding and abrasion resistant steels manufacturers can trust.
If you make products that require cutting edges that endure we suggest that you contact the SHARON representative nearest you and take advantage of this vast library of experience.
SOMOROFF-N.Y.
SHARONSTEEL
For 56 Years a Quality Name in Steel
174
SHARON STEEL CORPORATION, SHARON, PENNA.
CHICAGO, CINCINNATI, CLEVELAND, DAYTON, DETROIT, GRAND RAPIDS, INDIANAPOLIS, LOS ANGELES, MILWAUKEE, NEW YORK, PHILADELPHIA, ROCHESTER, SAN FRANCISCO, SHARON, SEATTLE, MONTREAL, TORONTO

may be conducted into the pressure chamber to permit measuring various phenomena.
For further information circle No. 1345 on literature request card, page 48-B.

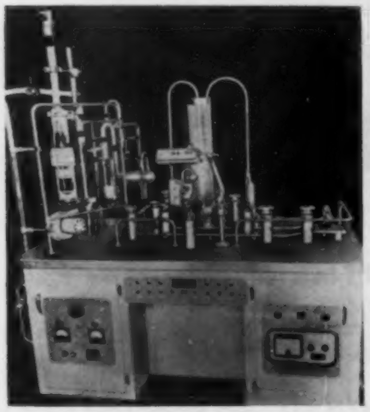
Bend Tester

Steel City Testing Machines has announced a new guided bend testing machine designed to test butt-welded samples. The machine has its own hydraulic load-applying means. Different fixtures for different thicknesses of metal can be interchanged.

When testing a given thickness there is no need to remove any of the fixtures between tests, thereby keeping dies in perfect alignment. As the lower die retracts at the conclusion of a test, an ejection device operates to remove the specimen from the lower die. Operator can pick it out with his hands after the machine has completed its cycle. The tester is 70 in. high, occupies a floor space of approximately 18 by 24 in., has a 15,000 lb. capacity and employs a ½-h.p. motor.
For further information circle No. 1346 on literature request card, page 48-B.

Gas Analysis

A new gas analyzer which measures traces of hydrogen, oxygen and nitrogen in metals has been announced by Fisher Scientific. It is being used to determine gases in titanium, nickel, manganese, niobium, vanadium, zirconium and steel. The vacuum fusion furnace and extraction tube are interchangeable and connected to the analytical train through a cold trap and ball-and-socket joint. Vacuum fusion analysis takes 10 to 20 min., hydrogen separation 30 sec. An auxiliary oxygen analyzer may be connected to the train.



For further information circle No. 1347 on literature request card, page 48-B.

Spectroanalysis

Intercontinental Electronics Corp. has announced the automatic Spectro-Lecteur, a direct reading spectrographic analyzer which permits measurement of instantaneous values and therefore direct reading of analysis results without resorting to integration. The automatic Spectro-Lecteur includes two photomultipliers; one views the line of the basic metal in the alloy, and the other travels automatically along the focal plane of the spectrum to detect the radiations from the line of each element in turn, according to a pre-arranged program. The output of the two photomultipliers is fed to two identical amplification

channels. Each channel comprises a preamplifier (containing input filters and load resistors), a main amplifier, a band filter, a rectifier, a time constant network and a milliammeter for direct reading of the output. The outputs of the two channels are fed to a chart recorder that marks the instantaneous value of their ratio on a graph.

For further information circle No. 1348 on literature request card, page 48-B.

Laboratory Mill

Loma Machine Mfg. Co. displayed an 8-in. wide 2-high/4-high combination rolling mill at the National Metal Show in Chicago, November 4 to 8. This machine offers facilities for hot and cold rolling of flat or shaped products in one machine.

For further information circle No. 1349 on literature request card, page 48-B.

Salt Bath Pump

A new high-temperature pump for handling molten salt and other hot liquids up to 2000° F. has been announced by Ajax Electric Co. The pump is fabricated of a limited number of heat resisting alloy parts. Using an air supply of 90 psi., the pump can handle 600 lb. of molten salt a minute; with a 60 psi. supply, 450 lb. a minute.

For further information circle No. 1350 on literature request card, page 48-B.

Chromalloy-Stainless Sheet

Chromalloy Corp. has announced a chromalloy-stainless sheet which can replace Type 430 in some applications. The core of this sheet is SAE 1010 annealed steel. Through high temperature diffusion of chromium into the 1010 steel, a stainless surface is formed. It is integral with the base metal and cannot be separated from it. The sheet can be bent and formed, staked, drawn or welded. It withstands operating temperatures of 1200° F. indefinitely and 1500° F. for hundreds of hours. At present it is produced in sizes up to 2 by 5 ft. and gages 16 to 24.

For further information circle No. 1351 on literature request card, page 48-B.

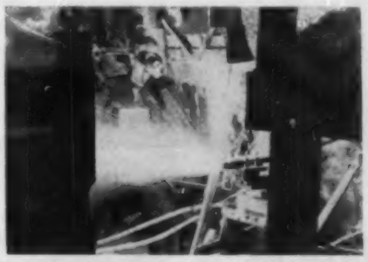
Cold Treatment

A freezer for the stabilization of austenitic stainless steels and tool steels has been announced by Cincinnati Sub-Zero Products. Model 3SR 120-47 has a 47 cu. ft. chamber and a net thermal capacity of approximately 6000 Btu. per hr. at −120° F. Using convection fluid, it will chill 250 lb. of steel per hr. from ambient to −120° F. For faster and more uniform chilling, the chamber is equipped with convection fluid agitator.

For further information circle No. 1352 on literature request card, page 48-B.

Optical Pyrometer

An optical pyrometer with a high-temperature range to 7600° F. has been announced by Leeds & Northrup Co. The instrument can be used for such applications as vacuum melting, manufacture of cermets, in research and in jet-engine component tests.



For further information circle No. 1353 on literature request card, page 48-B.

Welding Flux

Ampco Metal, Inc., has announced a new welding flux which is suitable for general brazing, cast-iron welding and cast-iron brazing with the oxy-acetylene process. Ampco-Braz flux No. 2 has good wettability, is non-

fuming and nontoxic, depresses filler metal bubbling and fuming and has deep penetration.

For further information circle No. 1354 on literature request card, page 48-B.

Spring Tester

A new tester for checking loads and deflections of compression and extension springs has been announced by Carlson Co. Loads are shown on the large 15 in. dial by turning a handwheel; lengths are indicated on stainless steel rules in fractions of an inch and in decimals. Loads of ½ to 300 lb., spring diameters up to 4½ in., spring lengths of ¼ to 12 in. can be accommodated. A dial indicator can be applied to register deflections in thousandths of an inch.

For further information circle No. 1355 on literature request card, page 48-B.

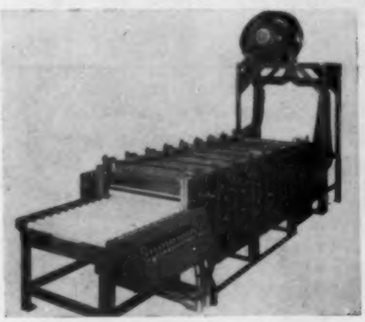
Flow Meters

A new line of dual-range flow meters has been announced by Air Reduction Sales Co. They are designed for inert-gas welding, flushing molten metals, laboratory service and other industrial applications. Switching from either flow range to the other is done by means of a piston-type selector valve. Flow rate within either range is controlled by a sensitive needle valve. The series includes seven direct-reading flow meters, each for a specific gas, and one general-purpose flow meter, provided with calibration curves, which will meter any of five gases. A combination of two or more flow meters can be used to proportion a mixture of gases.

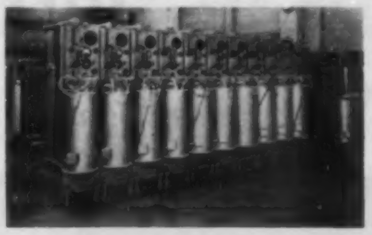
For further information circle No. 1356 on literature request card, page 48-B.

Sheet Cleaning

Industrial scrubbing machines designed to clean both the top and bottom surfaces of flat stock metal plates of oil, grit, and surface accumulations, have been announced by the Machine Div. of the Fuller Brush Co. The longer machine for cleaning extra heavy accumulations of surface dirt, is equipped with eight sets of brushes, six for scrubbing and two for scrub-rinsing away residual detergent solution, and will process sheets at a rate of 100 ft. per min. The shorter model has three sets of brushes, two for scrubbing and one for rinsing, and cleans flat metal plates at a rate of 60 ft. per min. Both have a maximum width capacity of 38 in. A detergent and water solution is pumped onto the plates as they are conveyed through the machine by means of feed rolls. They are then scrubbed and scrub-rinsed. The plates then pass through an air-squeegee and come out dry.



For further information circle No. 1357 on literature request card, page 48-B.



Creep Testing

A new 12,000 lb. creep rupture testing machine has been announced by Tatnall Measuring Systems Co. It has an 1800° F. split furnace, sealed

at the bottom to prevent stack effect. It has three heating elements with shunts to provide uniform temperature along the gage length. A bank of these machines coupled with a single dead-weight load maintainer makes it possible to get a large number of machines in a limited floor space. The lever arm is eliminated and the force is applied directly to the specimen.
For further information circle No. 1358 on literature request card, page 48-B.

Ultrasonic Processing

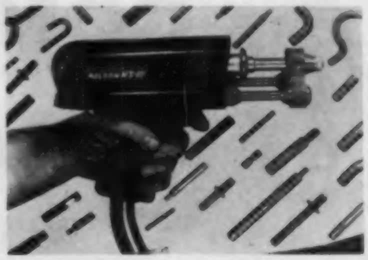
The General Ultrasonics Co. has announced new 5-gal. and 8-gal. tanks for ultrasonic cleaning, degreasing, pickling and electroplating. These new Sonitanks operate at a resonant frequency of 20 kc. per sec. Reinforced

transducer elements are attached by riveting. The treatment chambers are made of Type 302 stainless steel with input and output drains to allow for recirculation and filtering of the liquid medium. The 5-gal. tank operates with a 400 watt, 20 kc. ultrasonic generator, the 8-gal. tank with a 700 watt, 20 kc. generator.
For further information circle No. 1359 on literature request card, page 48-B.

Sulphur Determinator

A new automatic sulphur determinator for sulphur titrations has been announced by Lindberg Engineering Co. The titration is accomplished by the addition of a proper titrant to the test solution until there occurs a condition called an end point, which is determined photoelectrically.

When the initial color intensity of the test solution is attained, the flow of titrant is shut off and a signal light indicates the end of the titration.
For further information circle No. 1360 on literature request card, page 48-B.



Welding

A new stud welding gun has been announced by the Nelson Stud Welding Div., Gregory Industries, Inc. The plastic gun weighs less than 4 lb. and is 9 in. long, but will weld studs up through ½ in. in diameter.
For further information circle No. 1361 on literature request card, page 48-B.

Low-Temperature Cabinet

Revco, Inc., has announced an industrial low-temperature freezer capable of reaching temperatures to −150° F. The new model has a storage capacity

of 6.5 cu. ft. in outside dimensions of 60 by 28 by 42¾ in. It is refrigerated by sealed hermetic compressors.
For further information circle No. 1362 on literature request card, page 48-B.

Zinc Brightener

R. O. Hull & Co. has announced a new 503 zinc brightener for still and automatic plating. It is a balanced liquid formulation which is added to the plating solution. It resists break-down at high temperature, a gallon lasting for 50,000 or more amp.-hr. It brightens deep recesses as well as surfaces and produces a fine grain.
For further information circle No. 1363 on literature request card, page 48-B.

Laboratory Furnace

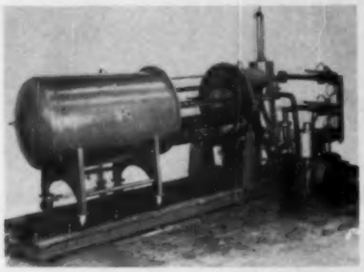
Brinkmann Instruments, Inc., has announced a new laboratory muffle

furnace for temperatures to 3200° F. This furnace employs neither protective atmosphere nor vacuum. The heating element of pure rhodium is wound around a tube of sintered impervious recrystallized aluminum oxide. The heating zone is then embedded in refractory ceramic which is surrounded by a sheet-steel housing. The furnace is available in 3 sizes, and uses single phase a.c. current at 220/230 volts.

For further information circle No. 1364 on literature request card, page 48-B.

Vacuum Metallizing

A new vacuum metallizing unit has been announced by NRC Equipment Corp. The model 3143 coating unit is useful where the volume of work is insufficient to utilize the capacity of



a large production coater. The new unit has a 5-ft. long, 42-in. diameter horizontal coating chamber which provides 12,000 sq. in. of coating capacity per load. Two filament rods and a planetary jig which accommodates four work holding rods are cantilevered from the one head of the chamber which remains stationary.

For further information circle No. 1365 on literature request card, page 48-B.

Recorder

A new electronic Dynamaster X-Y recorder has been announced by the Bristol Co. The new strip-chart recorder will automatically plot a con-

tinuous curve showing the relationship of one measured variable to another. The instrument will plot temperature versus pressure or other variables. The Dynamaster records on a 12-in. strip chart and is available in pen speeds up to 0.4 sec. for full scale traverse. Standard accuracy is 0.25%.

For further information circle No. 1366 on literature request card, page 48-B.

Steam Cleaner

A new steam cleaning machine has been announced by Circo Equipment Co. A full operating pressure is generated within 90 sec. The entire sys-

tem is protected from excessive pressures at three independent points. The machine is available in stationary or portable models of 120 gal. capacity. The portable units are mounted on a free-rolling carriage.

For further information circle No. 1367 on literature request card, page 48-B.

Strain Cages

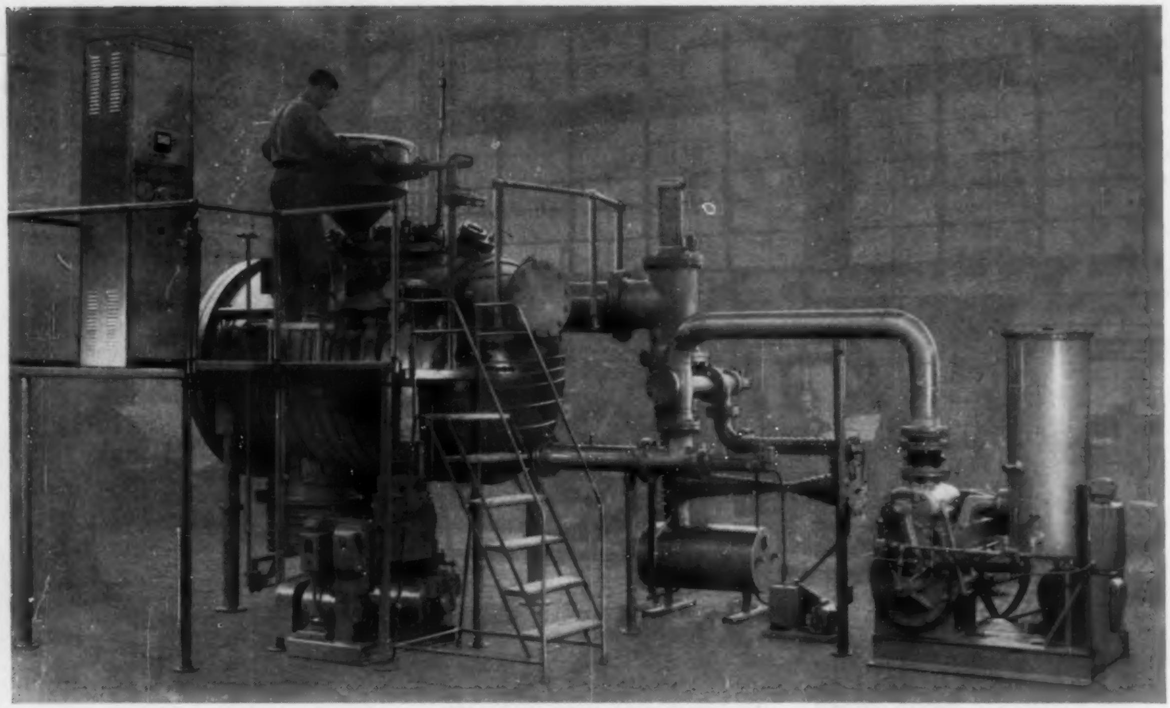
New SR-4 foil-type rosette strain gages have been announced by the Electronics and Instrumentation Div. of Baldwin-Lima-Hamilton Corp. The new rosettes have a sensitivity that is 8% higher than that of any previous rosettes. They need no lateral corrections except in the most precise testing problems, can withstand temperatures as high as 300° F. in continuous service and are thinner, more flexible and more easily applied than bonded wire SR-4 strain gages. Two sizes of bakelite bonded rosettes are available with gage lengths of ⅛ and ¼ in.

For further information circle No. 1368 on literature request card, page 48-B.

Cleaner

A new solvent that cleans, degreases and rustproofs all metal surfaces in one operation has been announced by Harry Miller Corp. Immunol is mixed with hot or cold tap water, a few ounces of the solvent to a gallon of water. It cleans by floating oil or foreign matter away. It is neutral, nontoxic and nonflammable, and can be applied by wiping, dipping or spraying.

For further information circle No. 1369 on literature request card, page 48-B.



New modular-type vacuum induction furnace—Model FIM-300—50 to 300 pounds capacity.

Here's your special vacuum furnace

. . . it comes from our standard stock . . . and it stays special

Like a lot of new fields, vacuum metallurgy is growing and changing fast, making it hard to plan processing that will match the market as years roll by.

Solution: *Modular Furnaces*

One sure answer to this predicament is to buy *modular* furnaces . . . units you can expand as the need arises. Such a furnace is our new 50 to 300-pound furnace.

It handles melts as small as 50 pounds efficiently. With the correct size crucible you can take the basic unit up to 300 pounds. Observation windows, a bridgebreaker, a charging cup with interlock, and a gauge-valve relay rack cabinet give you the controls you need for uncomplicated vacuum metallurgy.

If or when your needs call for even more critically controlled production, the basic unit is ready with built-in accommodations for such things as a sampling device, immersion thermocouple, and optical sight tube.

Semi-continuous operation, too

There's a 12-inch flange above the crucible for adding a bulk-charging chamber. The 36-inch diameter mold well will take a 34-inch mold table. When you want to go to semi-continuous production, these two changes will greatly expand your output. For example, you could pour six 300-pound ingots—1800 pounds—without breaking vacuum.

The mold well, by the way, is flanged and can be provided in a variety of depths. Even with the standard well you can pour in molds 48" deep.

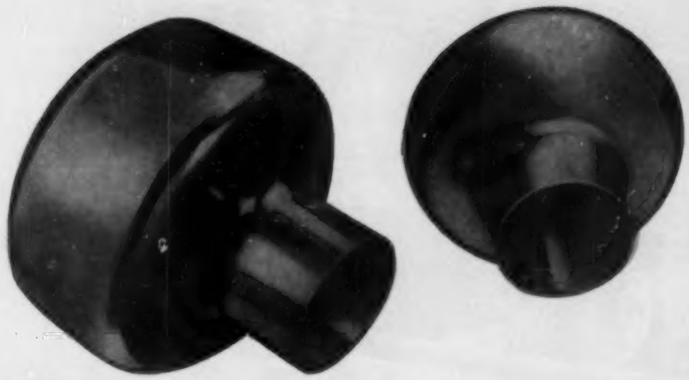
And so, if you want to break into vacuum metallurgy in a modest way with provisions for future expansion that will not sacrifice your initial investment, this is your furnace. Get to know it better by writing for our Bulletin P4-36.

Consolidated Electrodynamics

Rochester Division, Rochester 3, N. Y.

formerly Consolidated Vacuum

SALES AND SERVICE OFFICES IN PRINCIPAL CITIES



4 OF THE MANY STYLES OF THE ONE-PIECE SEAMLESS DOOR KNOBS FABRICATED FROM RUGGED REVERE BRASS STRIP.

REVERE BRASS STRIP

Stands the Gaff!

The one-piece door knobs shown are drawn from a single blank of Revere Brass Strip, presenting an attractively smooth, unbroken surface without the need for seams or welds.

Because they are made by a unique procedure the manufacturer tells us that the brass must stand up under mighty rugged going, and that to produce the quality knobs they do, at an economical production level, the brass they use must have:

1. *Uniformity of gauge.*
2. *Absence of any sign of fracture or crimping when drawn.*
3. *Consistently correct grain structure to insure a smooth, flaw-free surface on the finished knobs.*

The manufacturer also tells us that Revere Brass Strip has been filling that bill, with utmost satisfaction, for some time.

Revere Brass Strip may be able to help *you* make a better product at less cost. You'll never know until you talk it over with one of our TA's (Technical Advisor). There's no obligation, of course. And such a discussion could save you a substantial sum of money. Such has been the case many, many times.

COPPER ★ BRASS ★ ALUMINUM
1801
REVERE

REVERE COPPER AND BRASS INCORPORATED
Founded by Paul Revere in 1801
230 Park Avenue, New York 17, N. Y.

Mills: Baltimore, Md.; Brooklyn, N. Y.; Chicago, Clinton and Joliet, Ill.; Detroit, Mich.; Los Angeles and Riverside, Calif.; New Bedford, Mass.; Newport, Ark.; Rome, N. Y. Sales Offices in Principal Cities, Distributors Everywhere.

APPLICATION and EQUIPMENT new literature

1371. Abrasion Tester
Bulletin 5409 on new model standard abrasion testing set describes machine and its operation. *Taber Instrument Corp.*

1372. Air Washers
Bulletin No. 256 on acid-proof air washers for ventilation systems. Construction and accessories. *Automotive Rubber Co.*

1373. Alloy Steel
68-page "Aircraft Steels" includes revised military specifications. Also stock list. *Ryerson*

1374. Aluminum Bronze
8-page booklet on aluminum bronze bearing material which is forgeable, corrosion resistant, lightweight. *Mueller Brass*

1375. Aluminum Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

1376. Aluminum Extrusions
Folder lists alloys used, finishes, trade phraseology. *General Extrusions, Inc.*

1377. Aluminum Melting
Folder on electric furnaces for the aluminum alloy foundry. *Ajax Engineering*

1378. Annealing Furnaces
8-page illustrated booklet on continuous annealing furnaces. Schematic diagrams, photographs, and actual production data. *Drever*

1379. Atmosphere Equipment
4-page bulletin on exothermic and endothermic gas generators, ammonia dissociator. *C. I. Hayes*

1380. Atmosphere Furnace
4-page description of furnace which heat treats, quenches and cools under controlled atmosphere. Furnace for solution heat treating of aluminum and oven for tempering springs. *W. S. Rockwell*

1381. Atmosphere Generators
New 4-page bulletin I-457 includes flow charts and cost analyses of inert gas system. *Gas Atmospheres*

1382. Barrel Finishing
12-page booklet gives case histories, materials for barrel finishing. Equipment. *Minnesota Mining & Mfg. Co.*

1383. Batch-Type Furnaces
Bulletin SC-1 on mechanized controlled atmosphere furnaces. Three models diagrammed and described. *Dow Furnace*

1384. Bimetal Applications
44-page booklet, "Successful Applications of Thermostatic Bimetal", contains uses, formulas, calculations. *W. M. Chace*

1385. Blast Cleaning
Complete information on Malleabrasive for cleaning and finishing. *Globe Steel Abrasive*

1386. Boron Additive
6-page article on use of grainal as boron-additive alloy and properties of grainal steels. *Vanadium Corp.*

1387. Brazing
4-page reprint on gas-fired machine brazing. Case histories. *Selas*

1388. Brazing
4-page reprint on use of salt baths in production and small scale brazing of simple and complex assemblies. *Ajax Electric*

1389. Brazing
16-page pocket-sized guide to selective fluxing for low temperature silver brazing. *American Platinum*

1390. Brazing Alloys
Bulletin on application of six types of copper and silver brazing alloys. *United Wire & Supply*

1391. Buffing and Polishing
24-page catalog on cutting, coloring and double duty compounds for 12 metals, plastics and rubber. *Hanson-Van Winkle-Munning*

1392. Carbides
15 data sheets on Carmet carbide grades. Typical applications, analysis, physical characteristics and grain structure. *Allegheny Ludlum Steel Corp.*

1393. Carbon and Graphite
New 8-page bulletin on carbon and graphite for high temperature applications. Pertinent aspects of manufacturing process. *Speer Carbon Co.*

1394. Carbon Products
New 4-page bulletin on carbon and graphite products for the chemical processing and other industries. Pumps, valves, heat exchangers, etc. *National Carbon Co.*

1395. Carbon Refractories
Catalog section on carbon products for cupola furnaces gives physical properties of carbon refractories and describes applications. *National Carbon*

1396. Carburizing
16-page booklet on gas-carburizing processes and equipment. Discussion of suspended carburization, carbon restoration. *Surface Combustion*

1397. Centrifugal Castings
12-page bulletin gives analysis of ferrous and nonferrous alloys in which centrifugal castings are available. *Sandusky Fdry. & Machine*

1398. Centrifugal Pumps
Folder on new line of pumps. Features, engineering data. *General Ceramics*

1399. Ceramics
4-page bulletin D2-56 on physical properties of 10 industrial ceramics. Fabrication methods and important service features. *McDanel Refractory Porcelain Co.*

1400. Chemical Analyzer
Data on Autrometer, automatized chemical analyzer. Performance, applications. *Philips Electronics, Inc.*

1401. Chromate Coatings
Data sheets on Luster-on 50 conversion coating for manual or automatic plating. Bath make-up, operating conditions, typical cycle. *Chemical Corp.*

1402. Chromate Finishing
File on chromate conversion coatings for prevention of corrosion and paint-base treatment of nonferrous metals. *Allied Research Products*

1403. Chromium Plating
Bulletin CFC-1 on advantages of crack-free chromium plating process. *Metal & Thermit Corp.*

1404. Cleaner
Service report on composition for reverse current cleaning of steel. Application cycle. *Oakite*

1370. Super-Strength Steels

Structural steels with yield strengths of 55,000 to 150,000 psi. are considered in this 20-page booklet. Of higher strength than the high-strength low-alloy steels as well as carbon struc-

tural steels, they have other advantages (depending on composition), including strength at moderate temperatures, toughness at low temperatures, corrosion resistance and wear resistance. The properties of 15 steels in this class made by 7 steel producers are charted. Compositions, forming characteristics and uses are included. *Climax Molybdenum Co.*

1405. Cleaners
4-page bulletin No. E-1 on five cleaners for power washers, soak tanks, electrolytic cleaning, emulsion cleaning. *Park Chemical*

1406. Cleaners
Folder on immersion, electrolytic, spray cleaners, phosphate coaters, strippers, drawing compounds, additive agents. *Northwest Chemical*

1407. Cleaning
8-page bulletin on surface active agents for the metalworking industry. Properties. *E. F. Houghton & Co.*

1408. Coated Pipe
4-page folder on new plastic-coated steel pipe and tubing. How it solves the problem of pipeline corrosion. *Republic Steel*

1409. Cobalt Alloy
12-page booklet, "Haynes Alloy No. 25", tells of the unique properties of this cobalt-base alloy. *Haynes Stellite*

1410. Cold Rolled Steels
32-page booklet on stainless, alloy and carbon spring steels, and other specialties. Melting, temper, finishes. *Crucible Steel*

1411. Compressors
12-page bulletin 126-A on application of turbo compressors to oil and gas-fired equipment used in heat treating, agitation, cooling, drying. Performance curves, capacities. *Spencer Turbine*

1412. Construction Kit
Folder and 60-page booklet on construction kit of selected standard elements to be used in solving engineering problems and instruction. *C. R. Carlson Co.*

1413. Controller
Data sheet on thermocouple Electromax signaling controller. Specifications. *Leeds & Northrup*

1414. Copper Alloys
40-page technical data book on eleven copper alloys. Properties, cleaning, annealing. *Seymour*

1415. Copper and Brass
New 60-page warehouse stock list gives items and sizes carried in stock. *American Brass*

1416. Copper Alloys
48-page book contains tables of alloys with composition, typical uses, general working, mechanical, electrical properties, hardness, ASTM specification numbers. *Revere*

1417. Copper Alloys
60-page catalog on phosphor bronzes, nickel silvers, beryllium copper, cupronickel. Chemical and physical data. Engineering tables. *Riverside-Alloy Metal*

1418. Creep Testing
Bulletin RR-13-54 on new creep testing machine. *Riehle*

1419. Creep Testing
Bulletin 4420 describes long-time creep test machines, creep-rupture machines and relaxation machines. *Baldwin-Lima-Hamilton.*

1420. Decimal Equivalents
2-color wall chart gives decimal equivalents. *Peninsular Steel Co.*

1421. Decimals
Wall chart 16 by 23 in. of decimal equivalents. *John Hassall, Inc.*

1422. Degreasers
Folder on vapor and solvent degreasers describes equipment and advantages. *Randall Mfg.*

1423. Degreasing
Bulletin on OPNT vapor degreaser describes and diagrams its construction. *Circo Equipment*

1424. Descaling Titanium
Bulletin 25-T on salt descaling of titanium and titanium alloys. History, recommended procedure, problems. *Hooker Electrochemical*

1425. Dew Point Control
Bulletin No. 21-C on instrument which indicates, records and controls dew point automatically. *Ipsen*

1426. Disintegrators
Catalog B-1 on disintegrator which will remove embedded broken tools. Specifications. *Jiffy Disintegrator*

1427. Dryers
New 52-page Bulletin D-100 on dryers for air, gas and liquids for low dew points. *C. M. Kemp Mfg. Co.*

1428. Ductile Iron
2-page Bulletin 14 describes characteristics, production, effect of heat treatment, types. *Advance Foundry Co.*

1429. Electric Furnaces
Bulletin HD-153 on furnaces using silicon carbide heating elements for duty to 2600° F. *Hevi Duty Electric Co.*

1430. Electric Furnaces
Catalog of electric furnaces and ovens, for hardening, tempering, annealing, drawing, drying, baking, enameling. *Cooley Electric Mfg.*

1431. Electric Furnaces
8-page Bulletin 570 on heat treating, melting, metallurgical tube, research and sintering furnaces. Custom designs for special requirements. *Pereny*

1432. Electrocoated Wire
8-page bulletin on new wire materials —Nickelply and Brassply, electrocoated steel wire. How it may be formed, bent and twisted without breaking the coating. *National Standard*

1433. Electron Tubes
12-page bulletin on industrial use and proper care of electron tubes. Log sheets for tube life records. *Machlett Laboratories*

1434. Flow Measurement
8-page Bulletin SC-1022 on instrument for measurement of flow rate of air and gases. *Selas Corp.*

1435. Flow Meter
12-page bulletin 115 on meter for flow metering and control. Tubes, floats, and accessories. Installation and maintenance. *Brooks Rotameter Co.*

1436. Flow Meters
Bulletin 203 on flow meter for gas used in heat treating. *Waukee Eng'g*

1437. Fluoroscopy
New 6-page reprint on modern techniques for using electronic fluoroscopy in examination of metals. Mechanism of image intensification, effect of target size on X-ray image, penetration effectiveness of various methods. *Philips Electronics*

1438. Formed Shapes
26-page catalog No. 1355 contains drawings and dimensions of more than 100 shapes. *Roll Formed Products Co.*

1439. Forgings
Series of articles on modern forging methods. *Hill Acme*

1440. Forgings
8-page bulletin on typical upset forgings. Advantages and metal saved. *Champion Rivet*

1441. Forgings
12-page booklet on how forged weldless rings and flanges are made. Case histories. *Standard Steel Works Div., Baldwin-Lima-Hamilton*

1442. Forgings
New folder on facilities for production of flat-die forged products. Electronic equipment used. *Smith-Armstrong*

1443. Forgings
94-page book on die blocks and heavy-duty forgings. 20 pages of tables. *A Finkl & Sons*

1444. Furnace
Description of new spheroidizing fur-

Studs for NELWELD process machined from Youngstown cold finished bars

Progressive fabricators rely on the Nelweld method for fast, dependable end-welding of studs to steel surfaces. This novel electric arc process—utilizing flux-filled steel studs—substantially reduces direct fastening costs when used to replace conventional time-consuming methods such as drilling, tapping, hard welding, through-bolting or the securing of straps and rivets.

To maintain their world-wide reputation for product quality and uniformity, Nelson Stud Welding, a division of Gregory Industries, Inc., uses Youngstown Cold Finished Bars as the basic material for stud production.

Youngstown Cold Finished Bars provide high machinability and greater uniformity of composition, structure and surface finish to help you increase production of more uniform parts. Always specify Youngstown—it's your best assurance of quality.

Why not call or write your nearest Youngstown District Sales Office today for additional information or metallurgical assistance?

Close-up of studs being bored to accomodate their charge of flux (top collet) and then cut-off (center collet). Two finished Nelweld studs, shown in the pan in foreground, were machined simultaneously in the 6-position machine. First operation—feed out and face; second—bore; and third—cut-off.

Set-up man is loading ¾-inch diameter Youngstown Cold Finished Bars into a 6-spindle Acme Gridley automatic screw machine.

THE YOUNGSTOWN SHEET AND TUBE COMPANY
Manufacturers of Carbon, Alloy and Yoloy Steel
General Offices - Youngstown 1, Ohio
District Sales Offices in Principal Cities

QUALITY YOUNGSTOWN SERVICE

Cold finished bars

nace installed at Budd Co., in Metal Minutes, Nov. 1956. *Sunbeam Corp.*

1445. Furnace
New bulletin on basic principles of electric furnace design. Cutaway models of 8 furnaces. Cost factors. *Holcroft*

1446. Furnace Charging
12-page brochure on eight models of charging machines for heating and melting furnaces. *Salem-Brosius*

1447. Furnace Fixtures
Bulletin 111 on cast Ni-Cr fixtures for gas carburizing. *Fahralloy*

1448. Furnace Loader
Bulletin on loader for heat treat furnaces. *Michigan Crane & Conveyor*

1449. Furnaces
Bulletin 1250-T on bell retort furnaces describes atmosphere system, construction and dimensions. *American Gas Furnace*

1450. Furnaces
Bulletin on electric heat treating furnaces describes five series and accessories. *Lucifer Furnaces*

1451. Furnaces
Bulletin SC-179 on gas-fired muffle furnace. Application in bright heat treatment and brazing. *Surface Combustion Corp.*

1452. Furnaces
Catalog on standard and special furnaces and ovens to 3000° F. *L & L Mfg.*

1453. Furnaces
Data on radiant aluminum die casting furnaces. *J. A. Kozma Co.*

1454. Furnaces
Folder describes complete set up for heat treatment of small tools, including draw furnace, quench tank and high temperature furnace. *Waltz Furnace*

1455. Furnaces
52-page book on gas, oil and electric pot furnaces. 16 pages of drawings of various types of furnaces. *A. F. Holden*

1456. Furnaces
Folder on recirculating furnaces illustrates and describes 9 models and endothermic gas generator. *Standard Fuel Engineering Co.*

1457. Furnaces
High-temperature furnaces for temperatures up to 2000° F. are described in bulletin. *Carl-Mayer Corp.*

1458. Furnaces
Lists of surplus furnaces for sale. *Joe Martin Co.*

1459. Furnaces, Heat Treating
12-page bulletin on conveyor furnace, radiant tube gas heated, oil or electrically heated. *Electric Furnace Co.*

1460. Galvanizing
Story of galvanizing fencing at Colorado Fuel and Iron in Metal Minutes, Aug.-Sept., 1957. *Sunbeam*

1461. Gas Blenders
Bulletin GB 8-57 on machine to control gas mixing. *Gow-Mac Instrument Co.*

1462. Gas Unit
Bulletin HD-257 on gas preparation unit gives gas composition and chemical reactions. *Hevi Duty Electric*

1463. Gold Plating
Folder gives data on plating to obtain a hard bright gold finish. *Technic, Inc.*

1464. Graphite
6-page revised bulletin No. 435 on colloidal graphite for surface coatings and impregnation. *Acheson Colloids*

1465. Grinding Machine
Folder on grinding machine with continuous inspection. Specifications. *Cleveland Grinding Machine Co.*

1466. Hardfacing
New 8-page booklet on hardfacing electrodes gives chemical composition, properties, applications, procedures. Iron, cobalt base alloys and cast tungsten carbide. *Haynes Stellite*

1467. Hardness Numbers
Pocket-size table of Brinell hardness numbers incorporating other tabular information. *Steel City Testing*

1468. Hardness Tester
Bulletin on Brinell tester with test head for deep and offset testing. *King Tester*

1469. Hardness Tester
Catalog 72-1 on Leitz miniload tester for Vickers and Knoop hardness and standard hardness testers for Rockwell and Brinell tests. *Opto-Metric Tools*

1470. Hardness Tester
Data on hardness testing scleroscope with equivalent Brinell and Rockwell C numbers. *Shore Instrument*

1471. Hardness Tester
4-page bulletin on portable metal hardness tester for any shape or metal. Ranges, features. *Newage Industries*

1472. Hardness Tester
20-page book on hardness testing by Rockwell method. *Clark Instrument*

1473. Hardness Testers
4-page bulletin on hardness tester for regular and superficial Rockwell tests. Special features and accessories. *Torsion Balance*

1474. Hardness Testers
20-page bulletin on models, applications and how to use superficial hardness testers. *Wilson Mechanical Instrument*

1475. Hardness Testing
Bulletin No. A-18 on Alpha Co. Brinell hardness testing machines. *Gries Industries*

1476. Heat-Resistant Alloys
Catalog and stock list of sheets, plates and bars of heat-resistant alloys. *Rolled Alloys, Inc.*

1477. Heat Treating
Bulletin on completely mechanized heat treat lines. 24 basic mechanisms. Steps in building automated lines. *Surface Combustion Corp.*

1478. Heat Treating
Bulletin describes baskets, crates, trays, furnace parts for heat treating. *Stanwood*

1479. Heat Treating
8-page article on heat treatments for ductile iron. Process for developing tensile strength from 60,000 to 150,000 psi. and elongation to 25%. *International Nickel*

1480. Heat Treating
12-page bulletin on heat treating equipment. Applications and special features of 19 different types of furnaces including shaker hearth, conveyor, high vacuum, elevator-type brazing. *Pacific Scientific*

1481. Heat Treating
Monthly bulletin on used heat treating and plating equipment, available for immediate delivery. *Metal Treating Equipment Exchange.*

1482. Heat Treating
New 24 page catalog on effect of steam atmosphere heat treating on various metals. *Leeds & Northrup Co.*

1483. Heat Treating Ammonia
24-page "Guide for Use of Anhydrous Ammonia" describes heat treating and other metallurgical uses. *Nitrogen Div.*

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FOR FERROUS METAL-MELTING

type of equipment	metals melted	use of cement	Norton cement recommended: number	maturing temperature		how applied
indirect arc	alloy iron and steels	lining	RA 1307	1150°C	2100°F	rammed
		patching	RA 1307 RA 1162	1150°C 1000°C	2100°F 1850°F	rammed rammed
direct arc	alloy steel and malleable iron	troweling around electrodes	RA 1162	1000°C	1850°F	trowled
		lining roof and around electrodes	RA 1307	1150°C	2100°F	rammed
high frequency induction	stainless steel and refractory alloys	lining	RM 1170	1150°C	2100°F	rammed (dry)
		patching large furnaces	RM 1152	1200°C	2200°F	rammed
		patching small furnaces	RM 1992	1100°C	2000°F	troweled or rammed
ladles	iron and steel	lining	RA 1307	1150°C	2100°F	rammed

FOR NONFERROUS METAL-MELTING

type of equipment	metals melted	use of cement	number	maturing temperature		how applied
low frequency induction	Al, Te, Si bronzes	lining	RM 1140	1250°C	2300°F	rammed
	general purposes	lining	RA 1307	1150°C	2100°F	rammed
indirect arc	brasses and bronzes	lining and patching	RA 1307	1150°C	2100°F	rammed
crucible melting furnaces ■	brasses and bronzes	lining and patching	RC 1188	1100°C	2000°F	rammed
reverberatory furnaces ▲	brasses and bronzes	lining and patching	RC 1188	1100°C	2000°F	rammed

■ Cement not in contact with metal; used in combustion chamber. ▲ Cement in contact with metal.

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1484. Heat Treating Belts
Catalog of conveyor belts and data for their design, application and selection. *Ashworth Bros.*

1485. Heat Treating Fixtures
Folder on carburizing boxes, trays, heat treat fixtures and baskets. *Misco*

1486. Heat Treating Fixtures
4-page folder on retorts, baskets, trays, carburizing boxes, fans for heat treating. *Aluminum & Architectural Metals Co.*

1487. Heat Treating Fixtures
12-page bulletin on wire mesh baskets for heat treating and plating. *Wiretex*

1488. Heat Treating Fixtures
24-page catalog on heat and corrosion-resistant equipment for heat treating and chemical processing. 30 classifications of equipment. *Pressed Steel*

1489. Heat Treating Fixtures
New 32-page catalog G-10A lists process equipment, heavy welded fabrications, muffles, trays, fixtures for furnaces, heat-treating equipment, pickling equipment. *Rolock*

1490. Heat Treating Supplies
Data sheets on carburizing, hardening, tempering, nitriding salts, metal cleaning and rust prevention materials. *Heatbath*

1491. Heaters
Bulletin on immersion heaters for electroplating solutions. *Glo-Quartz*

1492. Heaters
16-page publication GEA-5866 gives case histories of use of tubular heaters in shrinking machinery, extruding machines, radiant ovens and paint heaters. *General Electric*

1493. High-Strength Steel
New 24-page bulletin on steel bars made by elevated temperature drawing. Strength without heat treatment, machining data, fatigue resistance, wearability. *LaSalle Steel*

1494. High-Strength Steel
26-page booklet on properties, uses, applications of high-tensile low-alloy steel. *Jones & Laughlin*

1495. High-Temperature Alloy
14-page bulletin on Udimet 500 gives composition, heat treatment, machinability, hot working characteristics and properties. *Utica-Metals Div.*

1496. High-Temperature Belts
Bulletin T-241 on belts of high-temperature alloy for heat treat furnaces. *Electro-Alloys*

1497. High-Tensile Steel
8-page bulletin on properties and composition of N-A-X high-tensile steel. Examples of resistance to impact, fatigue, abrasion and corrosion. *Great Lakes Steel*

1498. Induction Heater
New 8-page bulletin on 60-cycle induction heater for aluminum, copper, brass and steel. Installations, billet heater selection chart for aluminum. *Magnethermic Corp.*

1499. Induction Heating
Folder 15C8053C gives advantages of induction heating and specifications and dimensions of induction heater. *Allis-Chalmers*

1500. Induction Heating
New bulletin on remote heating station for motor generator induction heating equipment. *Lindberg Engineering Co.*

1501. Induction Heating
12-page booklet B-6519 on equipment for induction heating for forging, hardening, annealing and metal joining. *Westinghouse Electric*

1502. Induction Heating
60-page catalog tells of reduced costs and increased speed of production on hardening, brazing, annealing, forging or melting jobs. *Ohio Crankshaft*

1503. Induction Melting
Bulletin 70 on furnace. Controls, designs. *Inductotherm Corp.*

1504. Insulating Firebrick
8-page bulletin R-43 gives description of relationship between heat losses and weight of refractory lining. *Refractories Div., Babcock & Wilcox*

1505. Lab Test Dies
Complete information on multi-motion laboratory test specimen dies. *Haller*

1506. Laboratory Equipment
New bulletin on cutting test specimens describes methods for different types of metals. Price list. *Sieburg Industries*

1507. Laboratory Equipment
16-page Laboratory Spotlight lists optical equipment and instruments for metallurgical laboratory. Cut-off machines, polishing tables, etc. *Harshaw Scientific*

1508. Laboratory Furnaces
Folder describes and illustrates tubular furnace for use in tensile testing, and control panels. *Marshall Products*

1509. Laboratory Instruments
20-page booklet on gage laboratory instruments. Layout of a gage laboratory. Description of each instrument. *Sheffield*

1510. Leaded Steels
New 16-page booklet on basic characteristics, mechanical properties and workability of leaded steels. Case histories. *Copperweld Steel Co.*

1511. Low-Alloy Steel
60-page book on high-strength low-alloy steel, properties, fabrication and uses. *U.S. Steel*

1512. Low-Carbon Stainless
"Melting Low-Carbon Stainless Steel" shows advantages in use of new low-carbon chromium alloy for producing extra-low-carbon grades. *Electro Metallurgical*

1513. Lubricant
8-page booklet, "Biggest Ounce of Protection", tells of lubrication with colloidal graphite products. *Grafo Colloids*

1514. Lubricants
16-page brochure on history and development of molybdenum disulfide lubricants. Selection table, uses, bonded solid film lubricating coatings. *Alpha Molykote Corp.*

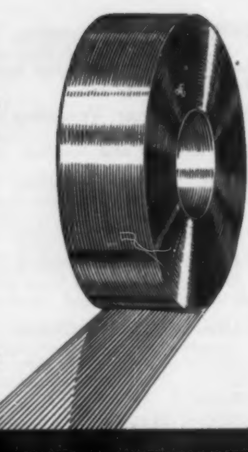
1515. Machining Alloy Steels
24-page bulletin on economical combination of microstructure, tool form, cutting speed and feed for each machining operation. *International Nickel*

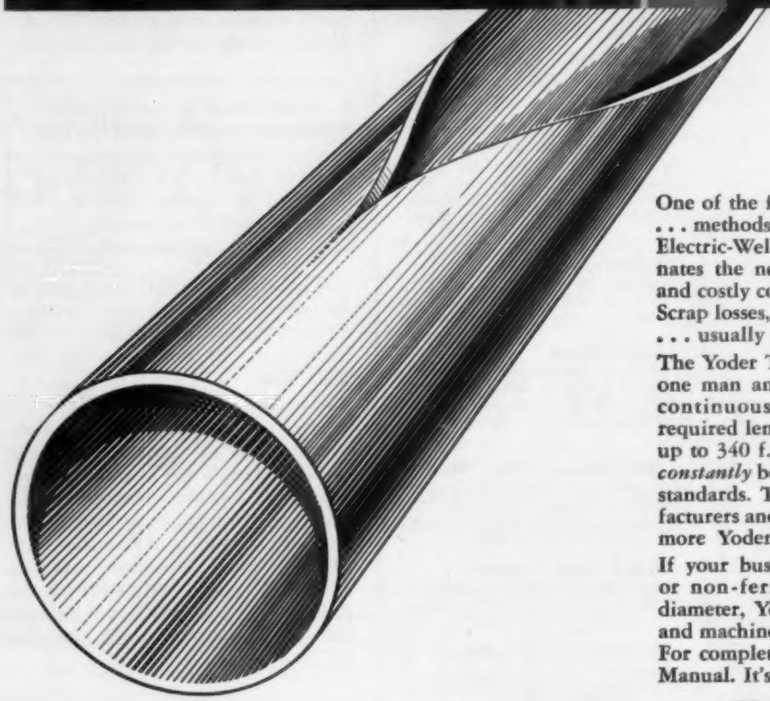
1516. Machining Copper
12-page bulletin on machining properties, practices, feeds, speeds, tool design. *Ampco*

1517. Machining Stainless
New pocket-size slide chart on how to machine the popular grades of stainless. Workability of stainless in blanking, deep drawing, stamping, forging, etc. *Carpenter Steel*

1518. Machining Titanium
8-page bulletin on turning, milling, drilling, tapping, grinding. Recommendations for each. Typical properties of titanium. *Mallory-Sharon Titanium Corp.*

1519. Magnesium
42-page booklet on wrought forms of magnesium. Includes 31 tables. *White Metal Rolling & Stamping*





1520. Magnesium-Zirconium
10-page reprint on an investigation of zirconium chloride, zirconium fluoride, 40% zirconium-magnesium material for making magnesium zirconium alloys. *Titanium Alloy Mfg. Div.*

1521. Malleable Iron
Brochure on selection of standard and pearlitic malleable iron castings. Cost savings through the use of malleable. *Malleable Founders' Society*

1522. Manganese
9-page article on electromanganese. Manufacturing procedures, product characteristics, uses. In Foote Prints, V. 28, No. 2. *Foote Mineral Co.*

1523. Marking Metal
Bulletin on electromark process. Equipment. Operating instructions. *Electromark Corp.*

1524. Meehanite Castings
4-page data folder on heat treatment of different grades of Meehanite castings. Improving strength, toughness and hardness. Austempering, martempering. *Meehanite Metal Corp.*

1525. Melting Aluminum
Bulletin 310 on furnaces for melting aluminum. *Lindberg Engineering Co.*

1526. Melting Furnaces
48-page book 9A on line of standard furnaces from research to 200-ton steel mill types. *Lectromelt Furnace Div.*

1527. Metal Forming
Folder on rolling mills, swaging machines, wire shaping mills, wire and tube drawing machines. *Fenn Mfg.*

1528. Metallograph
12-page bulletin on desk-type and research metallographs. Accessories, illuminating systems, specifications. *American Optical*

1529. Metalworking Saws
New 64-page catalog 31 on burs, files, grinding points, metalworking saws, voltammeters, electric etchers. *Martindale Electric Co.*

1530. Microhardness Tester
Bulletin describes the Kentron microhardness tester. *Torsion Balance Co.*

1531. Microscopes
Catalog of metallograph and several models of microscopes. *United Scientific*

1532. Molybdenum Alloying
1-page chart gives weight of ferro molybdenum addition needed by foundry for molybdenum contents in castings up to 1.50%. *Climax Molybdenum*

1533. Nitriding
Data on process for nitriding stainless steel. *Standard Steel Treating*

1534. Nondestructive Testing
8-page bulletin on equipment for nondestructive testing of bars, rods, tubing. *Magnetic Analysis.*

1535. Nonflammable Rust Preventive
Bulletin on rust preventive compound which is water soluble, nontoxic and nonflammable. *Production Specialties*

1536. Oil Quenching
8-page brochure tells in detail how carbon steel often can replace alloy steel when additive is used in the quenching oil. *Aldridge Industrial Oils*

1537. Openhearths
12-page booklet shows how openhearths are built. Furnace binding, refractories, combustion and controls, and mechanical equipment. *Loftus Engineering*

1538. Optical Instruments
Ways to use optical instruments in manufacturing and inspection. Magnifiers, microscopes, wide field tubes, macroscopes and comparators discussed. *Bausch & Lomb Optical*

1539. Ovens
New 16-page bulletin 157 on ovens for baking, drying, curing and heat treating. Batch and conveyor types. Air recirculating and heating systems. *Young Brothers Co.*

1540. Perforated Metals
New 4-page folder gives ordering specifications and patterns. *Wickwire Spencer Steel Div., Colorado Fuel and Iron Corp.*

1541. Permanent Magnets
New 12-page booklet on permanent magnets, Thermistors and Thyrite varistors tells how they can be used in design of electrical equipment. *Metallurgical Products Dept., General Electric Co.*

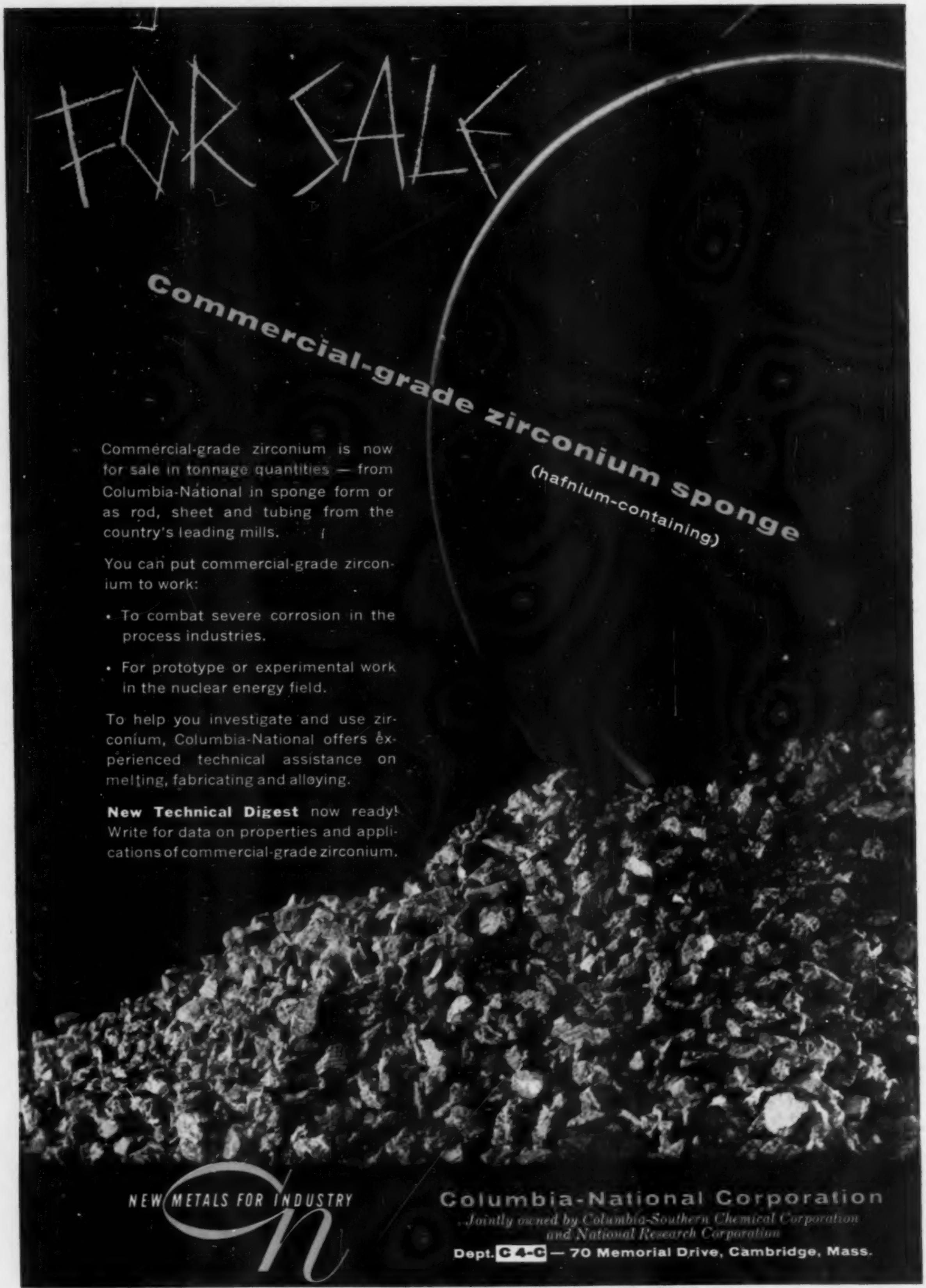
1542. Phosphating
Folder on phosphating and metal protective coating materials. Purpose and make-up of each type of coating. *Turco*

1543. Photomicrography
Catalog E-210 on sliding base, high or low power photomicrographic equipment. *Bausch & Lomb*

1544. Pickling Baskets
Data on baskets for degreasing, pickling, anodizing and plating. *Jelliff*

1545. Pickling Baskets
12-page bulletin on mechanical picklers, crates, baskets, chain and accessories. *Youngstown Welding & Eng'g*

1546. Plating
New 8-page bulletin on automatic plating and anodizing machine. Deposition charts for nickel, tin, zinc, cadmium, copper. *Lasalco, Inc.*



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1547. Polishing
12-page discussion, "A Practical System for Preparing Metallographic Specimens", from Metal Digest, V. 2, No. 3. *Buehler*

1548. Powder Metallurgy
8-page reprint on parts made by sintering powdered metals. Advantages and limitations of the process. Surface treatment. *Pegasus International Corp.*

1549. Powdered Metals
Booklet on design, properties, production and application of brass and other nonferrous powder parts. 24 case histories. *New Jersey Zinc*

1550. Powdered Metals
New 12-page booklet on advantages of powder metal parts, how they are made, design, production. *Dixon Sintaloy*

1551. Precious Metals
Data on bright gold, bright silver, rhodium plating and salts. *Sel-Rex*

1552. Precision Casting
8-page bulletin on investment castings of various ferrous and nonferrous alloys. *Engineered Precision Casting*

1553. Precision Casting
12-page book on alloy selection and design for investment casting. *Arwood Precision Casting*

1554. Precision Finishes
Technical data folder on Roto-Finish process, chips and compounds. Line of standard and special machines. *Roto-Finish Co.*

1555. Protective Coatings
Folder 301 on industrial protective coatings of rubber, neoprene and other materials. *Arco Steel Fabricators*

1556. Pyrometers
Data sheet 1E-1 on high resistance indicating pyrometers. Special thermocouples for surface measurement, molten nonferrous metals, general immersion. *West Instrument Corp.*

1557. Quenching Oils
4-page bulletin on 3 types of quenching oil gives advantages of each. *E. F. Houghton & Co.*

1558. Radiography
16-page booklet on materials and accessories for industrial radiography. Guide to selection of film. Recommended development techniques. *Eastman Kodak, X-Ray Div.*

1559. Radiography
20-page bulletin on gamma radiography. Uses, sources, equipment. *Nuclear Systems Div., Budd Co.*

1560. Rare Earth Metals
29 references to recent applications of the rare earth metals in iron, steel and other ferrous alloys. *New Process Metals*

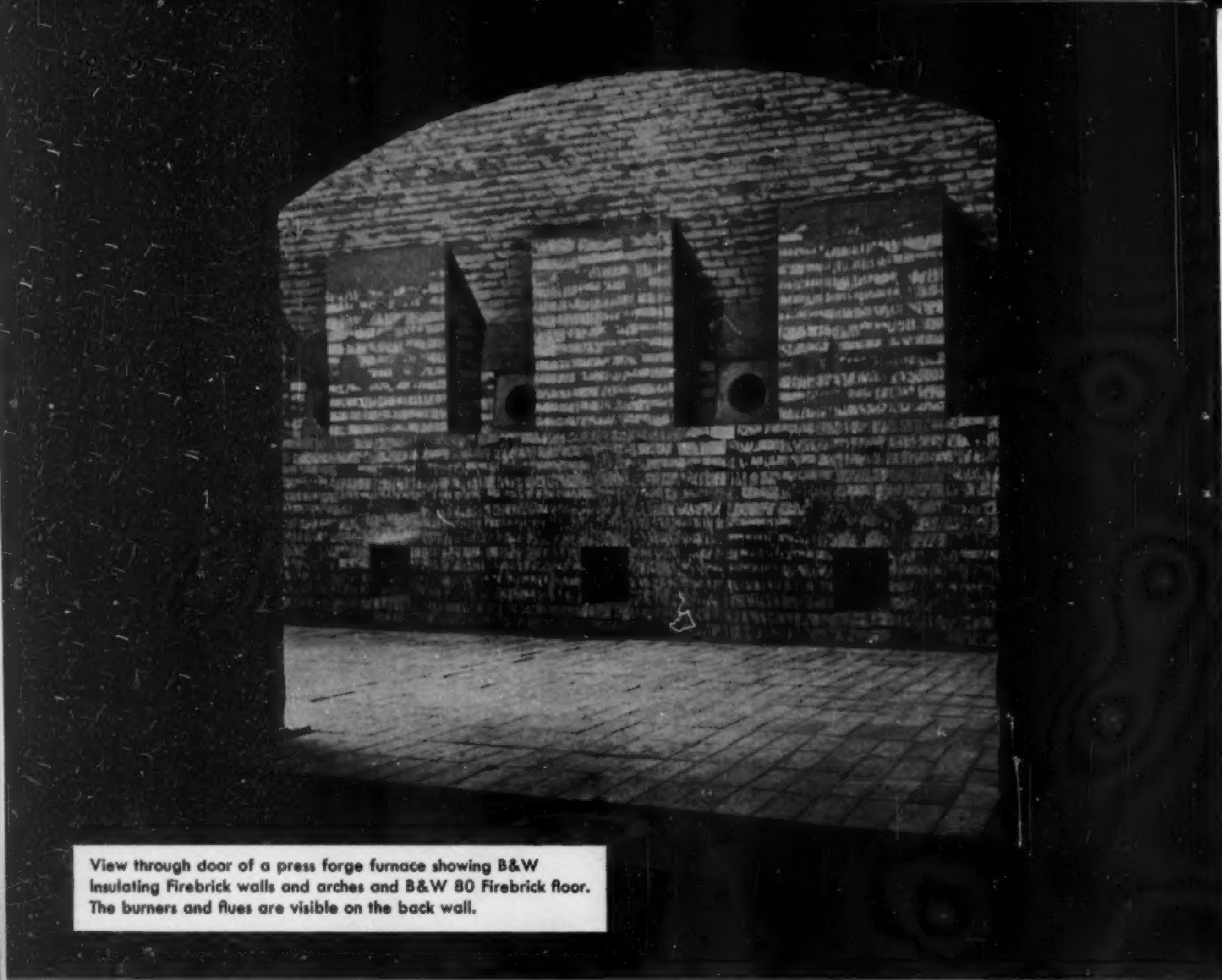
1561. Rare Earths
12-page handbook on rare earth chemicals, thorium. Applications of rare earths. *Heavy Minerals Co.*

1562. Recirculating Furnace
Bulletin on continuous-type recirculating furnace shows design of furnace, its operation and advantages. *Industrial Heating Equipment Co.*

1563. Refractories
New bulletin, 1992, on two high temperature Alundum castable refractories. Properties and how to use them. *Norton*

1564. Refractories
New refractory catalog sheets on Diablo-D refractory brick and Refracrete castable. *Refractories Div., Gladding, McBean & Co.*

(Continued on page 48-A)



View through door of a press forge furnace showing B&W Insulating Firebrick walls and arches and B&W 80 Firebrick floor. The burners and flues are visible on the back wall.

B&W Insulating Firebrick reduce fuel costs 15% and increase production

Experience paid off for this major steel producer. Aware of the benefits of B&W Insulating Firebrick in his drop forge furnaces, he built two new press forge furnaces with lightweight B&W IFB linings. The results were a minimum average fuel saving of 15% *and* increased production, since the entire heating process for certain grades of steel could now be accomplished in one operation. Here's why.

The lightweight and consequent low heat storage of B&W IFB linings keep the furnace walls at a uniform temperature to provide the most efficient heating conditions. Unlike heavier constructions, B&W Insulating Firebrick linings attain a uniform temperature faster with less fuel consumption.

In addition, B&W IFB linings respond quicker to temperature changes, permitting more accurate temperature control. In this instance, this not only prevented the cracking of tool and stainless steels, but helped reduce the total heating cycle, increasing production.

These forging furnaces use a 9″ B&W K-30 IFB wall backed up by B&W K-20 IFB. The K-30 is used as face brick because of its high temperature resistance. The K-20 is used as a backing because of its high insulating value. The hearth floor is of B&W 80 Firebrick for abrasion resistance and resistance against attack by mill-scale at the temperatures involved. Door linings are of B&W Kaocast and B&W Kaolite.

R-263

B&W REFRACTORIES PRODUCTS: B&W Allmul Firebrick • B&W 80 Firebrick • B&W Junior Firebrick • B&W Insulating Firebrick • B&W Refractory Castables, Plastics, and Mortars • B&W Silicon Carbide • B&W Ramming Mixes

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REFRACTORIES DIVISION
GENERAL OFFICES: 161 EAST 42nd ST., NEW YORK 17, N.Y.
WORKS: AUGUSTA, GA.

(Continued from page 47)

1565. Refractories
16-page catalog 101 on mullite refractories. Applications, ramming mixes, refractory mortars, patching mixes, castable refractories. Reference chart. *Refractories Div., H. K. Porter Co.*

1566. Refractories
40-page book lists super-refractories for heat treating furnaces and gives data on use in different kinds of furnaces. *Refractories Div., Carborundum*

1567. Refractory
Bulletin on castable refractories. How to use them. Properties of four types. *Standard Fuel Engineering*

1568. Resistance Alloy
New 16-page catalog on 60-16 nickel-chromium-iron alloy. Heating element design factors. *Hoskins Mfg. Co.*

1569. Rust Prevention
Bulletin No. 51 on anionic surface active agent for oil-soluble rust and corrosion inhibitors, emulsifying, wetting and dispersing agents. *Sun Oil Co.*

1570. Rust Prevention
Data sheets describe solvent type and emulsifiable type rust resisting compounds. *John Swift Chemical*

1571. Salt Bath Furnaces
Data on salt bath furnaces for batch and conveyorized work. *Upton*

1572. Sand Blasting
4-page bulletin 1256 on sand blasting machines for cleaning, deburring, surface preparation. *Leiman Bros.*

1573. Saws
Catalog C-55 describes 35 models of metal-cutting saws. *Armstrong-Blum*

1574. Sodium
40-page booklet on handling metallic sodium gives typical sodium-using processes, equipment installation, recommendations for pumping and instrumentation. *U.S. Industrial Chemicals*

1575. Sonic Thickness Tester
Measurement of wall thickness from one side by sonic method. *Branson*

1576. Spark Testing
20-page spark test guide features spark diagrams of 13 standard tool and die steels. *Carpenter Steel*

1577. Spring Wire
Selector guide for nickel alloy spring wire. Methods of heat treatment, processing of springs, stress relieving, annealing. *Techalloy Co.*

1578. Springs
Article in June-July 1957 Mainspring on hardening of beryllium-copper springs. *Associated Spring Corp.*

1579. Stainless Castings
Bulletin on advantages of corrosion-resistant castings. *Ohio Steel Foundry*

1580. Stainless Fasteners
New 24-page catalog 56-A lists sizes and types. 7000 items included. *Star Stainless Screw*

1581. Stainless Steel
Data sheet on Type 301 gives physical properties, corrosion and oxidation resistance, mechanical properties. *Allegheny Ludlum*

1582. Stainless Steels
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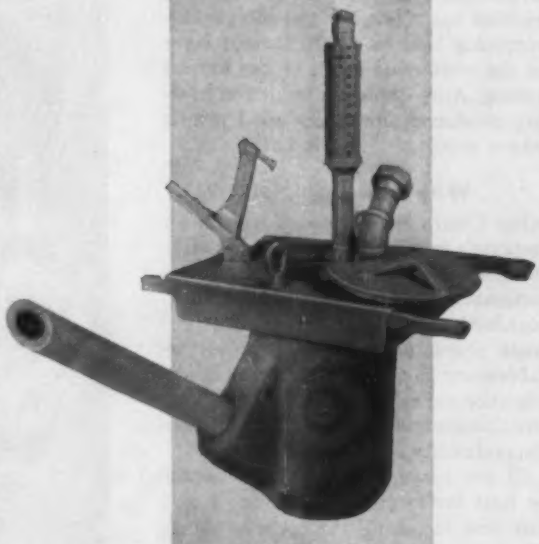
If you apply heat to aluminum LINDBERG can show you the better way

Lindberg-Fisher electric resistance melting and holding furnace with Lindberg Autoladle automatic pump.

Heat and aluminum have been Lindberg's twin babies for many years. If the manufacture of your product requires the application of heat to aluminum anywhere along the line we can help you do the job better. For years our engineering and research staff has been creating improved methods and developing more efficient equipment in this field.

Most recent development is the Autoladle (we call it "Little Joe"), the first practical automatic aluminum ladling unit yet devised. Used with Lindberg melting and holding furnaces "Little Joe" (shown at the right) makes automatic casting of aluminum fast, dependable and economical.

Lindberg's Melting Furnace Division makes a wide variety of melting and holding furnaces for aluminum, brass, bronze, tin, zinc, lead and other non-ferrous metals. These include aluminum induction, nose-pouring crucibles, electric resistance holding furnaces and big reverbs. For foundry, permanent mold or die-casting plant, independent or captive, there are Lindberg melting and holding furnaces to fit your requirements. If your problem in this field needs a special solution Lindberg's design staff can find it. Just get in touch with the Lindberg plant or the Lindberg Field Representative in your locality, or write Lindberg-Fisher Division, Lindberg Engineering Company, 2450 West Hubbard St., Chicago 12, Illinois. Los Angeles Plant: 11937 S. Regentview Ave., at Downey, California.



We call it

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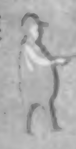


LINDBERG heat for industry

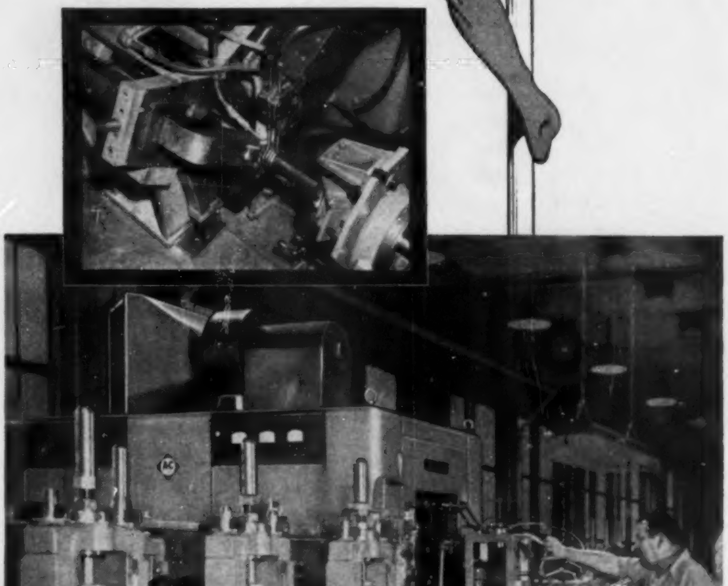
BRIDGEPORT BRASS COMPANY

Welds Aluminum Tubing at speeds up to

120 fpm

with an

Allis-Chalmers Induction Heater



Heart of Bridgeport's integrated mill is a 50-kw Allis-Chalmers induction heater. Coil is interchangeable to accommodate various tube sizes.

MR. HI FREQUENCY and the Allis-Chalmers induction heater solved an important production problem and gave Bridgeport Brass tremendous welding speed. Because aluminum has an abrupt melting point and a tendency to buckle, conventional arc welding yielded but a few feet per minute. By *confining* heat to a thin surface layer at the contacting edges of the formed tubing, Allis-Chalmers induction heating produced amazingly good results where previous methods failed.

Why Allis-Chalmers

Allis-Chalmers enhances induction heating's inherent speed with properly designed work handling equipment. An automatic timer and output controls, standard on Allis-Chalmers units, promote precision operation. Extensive laboratory facilities, unparalleled application experience, factory supervised installation and service assure complete dependability.

If you braze, solder, harden, anneal or heat for forging or melting, it will pay you to get all the facts on Allis-Chalmers induction heaters. See your nearby Allis-Chalmers representative or write Allis-Chalmers, Industrial Equipment Division, Milwaukee 1, Wis.

A-C ALLIS-CHALMERS

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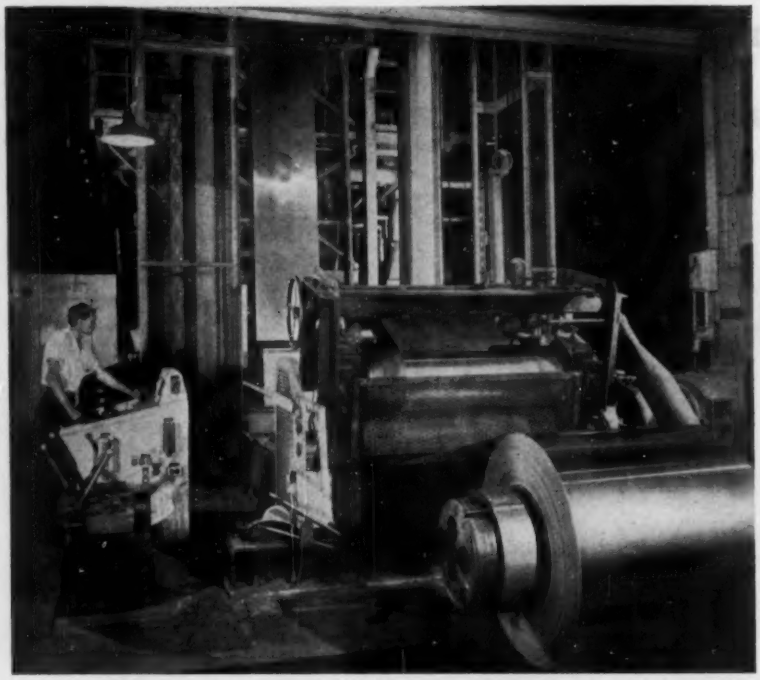


Tin plate continuously bright-annealed in direct gas-fired vertical one-pass Selas furnace.

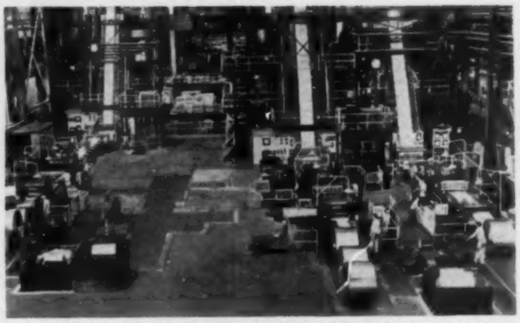
26 Single-Pass Selas Furnaces Heat-Process Strip Continuously... at Production Speeds

Selas combines Gradiation® Heating with process control to handle a variety of mill operations

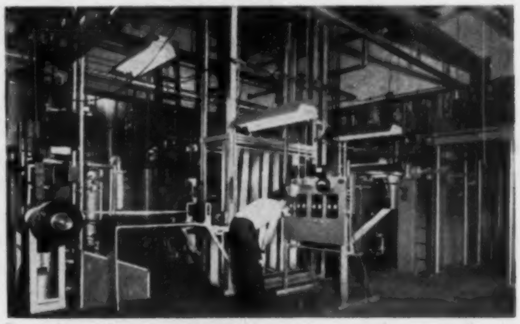
Throughout the nation's metal-producing industry, Selas has pioneered, designed and constructed single-pass strip heat-processing lines for bright annealing of steel . . . annealing stainless steel . . . tin reflow . . . galvanizing-annealing . . . preheat for galvanizing . . . preheat for annealing . . . blueing . . . special coatings . . . brass annealing . . .

In all these operations, radiant gas heat, precisely applied across the strip width, increases heating speed and produces unsurpassed uniformity in product quality.

- Compact single-pass design saves valuable floor space . . . avoids rolls in heated section, eliminating accompanying maintenance and product quality difficulties.
- Elimination of externally-prepared atmosphere in heating section reduces operating costs.
- Precise thermal control assures reproducible uniformity, regardless of gauge variations.



Annealing and galvanizing strip 48" wide is a high-speed, single-pass, continuous operation with Selas Gradiation heating.



Control panel governs temperature, strip speed, gas combustion and atmosphere composition in this Selas annealing installation.

Our engineers will be glad to discuss how Selas Gradiation methods can be tailored to your strip heat-processing needs. Address Dept. 311, Selas Corporation of America, Dresher, Pa.

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When aluminum needs heat treating it's time to look to LINDBERG

Lindberg Cyclone batch type furnace for heat treating aluminum castings.

When your use of aluminum makes it essential to apply heat for annealing or stress relief Lindberg can come up with the right equipment to do the job. Whatever the requirement our long experience in the application of heat to all types of metal can provide you with just the right furnace to fill your specific need. Maybe the batch type furnace shown here is what you need, or a big bottom quench for treating large aluminum sheets. No matter, Lindberg's staff of engineers, metallurgists and research technicians will face up to your problem. They'll help you find the answer, too, with the right type of equipment to treat aluminum or aluminum alloys to exact requirements of your product. Just get in touch with the Lindberg plant or the Lindberg Field Representative in your locality. Lindberg Engineering Company, 2450 West Hubbard St., Chicago 12, Illinois. Los Angeles Plant: 11937 S. Regentview Ave., at Downey, California.

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- X-ray Absorption Apparatus
- X-ray Crystal Analysis Units
- X-ray Tubes and Rectifiers
- X-ray Cameras, Sample Spinners, Pole Figure Devices and Accessories
- Autrometer—24 Channel automatic Element Analyzer
- X-ray Custom Built Equipment for Special Applications
- Geiger, Proportional, Scintillation and Flow Type Detectors
- Electronic Circuits for High Speed Detectors with Pulse Height Analyzers
- Decade Scalers and Ratemeters
- Electronic Timers
- Line Voltage Regulators
- Radio Compass Controls
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- Emission Microscopes
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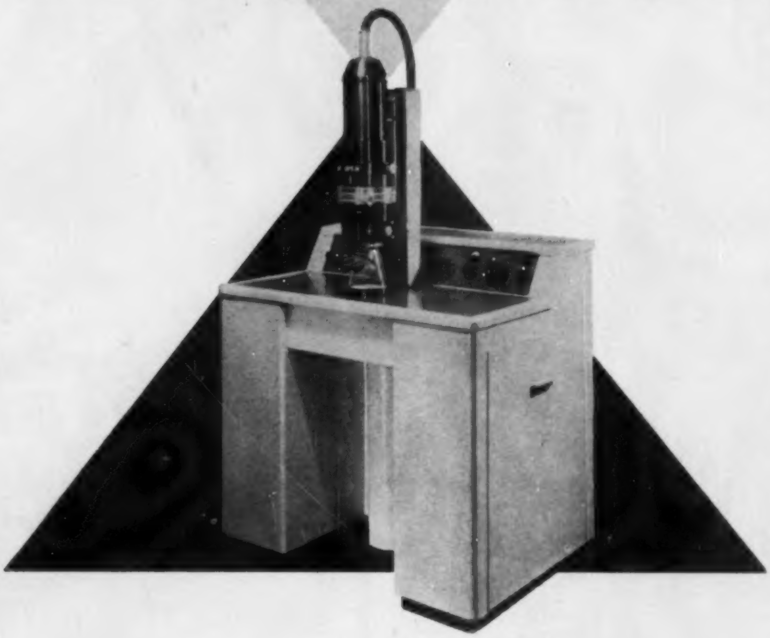
Norelco ®

NEW EM-75B ELECTRON MICROSCOPE



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The new Norelco EM-75B, a magnetic electron microscope of simple and unusual construction, bridges the gap between light optics and the highest extremes in image resolution. The remarkable resolution which this instrument offers, introduces the light microscopist to a new field of highly detailed microscopy at enlargements ranging from 1,200 to 12,000 diameters under direct observation.

A new astigmatic compensator affords higher resolution approaching the high resolution quality of larger, expensive and complex models. New provisions, such as flat plate camera and binocular viewer permits useful enlargements to 100,000x. Electron diffraction patterns for chemical identification of the materials under observation may now be obtained without changing the specimen position.

Called the "work horse" in electron microscopy, the moderately priced EM-75B is designed for maximum productivity. It may be installed in a relatively small laboratory space and is also ideally suited for mobile use – requiring only an electrical service outlet. It is rugged, requires no water cooling and has no electron tubes. Maintenance is thus reduced so as to become a negligible consideration.

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...available for demonstration or testing on your own material!

How would you like to run sawing tests on your own material... watch demonstrations under actual working conditions, of the world's most modern hack saws and band saws—and compare, if you wish, band sawing and hack sawing to see which type of saw is best for you?

You are cordially invited to come in to see and make use of the Sawing Demonstration Room—the most complete and up-to-date facility of its type in the country. Staffed by experienced metal sawing engineers and technicians, the Sawing Demonstration Room has been set up for your convenience. We sincerely believe you will find it interesting and helpful in your selection of metal sawing equipment.

Here, you will see the most modern single cut and automatic bar feed hack saws and band saws (including the *all new* MARVEL No. 81 and 81A Universal Hydraulic Band Saws equipped with the amazing "TRUE-LINE" Automatic Blade Control (Basic Patent Applied For) and using High Speed Steel Band Saw Blades.)

If you have any type of sawing problem, or if you would just like to come in and see a demonstration of the fine cutting MARVEL Saws can do, the Demonstration Room is always open to you.

MARVEL *Metal Cutting* SAWS
Better Machines—Better Blades

ARMSTRONG-BLUM MFG. CO.
5700 W. BLOOMINGDALE AVE., CHICAGO, ILL.

Handles for the gold-plated (left) and standard "Heavy" (center) Gillette safety razors are made from Anaconda leaded commercial bronze special-shape seamless tube, .4525" O.D., .371" I.D. "Regular" model (right) is of commercial bronze .395" O.D., .324" I.D.

Gillette shaves costs with Anaconda special-shape tubes

The problem: The Gillette Safety Razor Company, Boston, Mass., formerly used drawn shells for the handles of its famous line of razors. Press-fit assembly of components called for very close tolerances and suppliers of the drawn shell had difficulty in controlling the dimensions to the accuracy required. Rejects and production delays were becoming a costly problem to Gillette, and there was also excessive waste of material in trimming the shells after the knurling, grooving and rolling operations.

The solution: American Brass Company representatives suggested the use of special-shape (fluted) tubes to meet the tolerances required—in alloys suitable for the machining operations. Gillette tried the idea and now uses Anaconda special-shape tubes for handles of three models.

Long lengths of the tube are fed into high-speed, multiple-spindle machines which automatically convert the tube to razor handles ready for the plating room. Production is greatly increased, rejects and waste material are reduced to a minimum, and the uniformity of the handles simplifies assembly. Most important of all to the Gillette Safety Razor Company is the improved quality of the finished product.

Save Material and Production Costs: Special-shape seamless tubes—of copper, copper alloys or aluminum—in standard lengths, or cut to specified lengths, can save several steps in arriving at a finished product. The American Brass Company's French Small Tube Division are specialists in producing small tubes (up to ¾" O.D.) of special design and, in addition to maintaining a wide range of stock dies, are ready to cooperate fully in the development of new shapes to meet specific requirements.

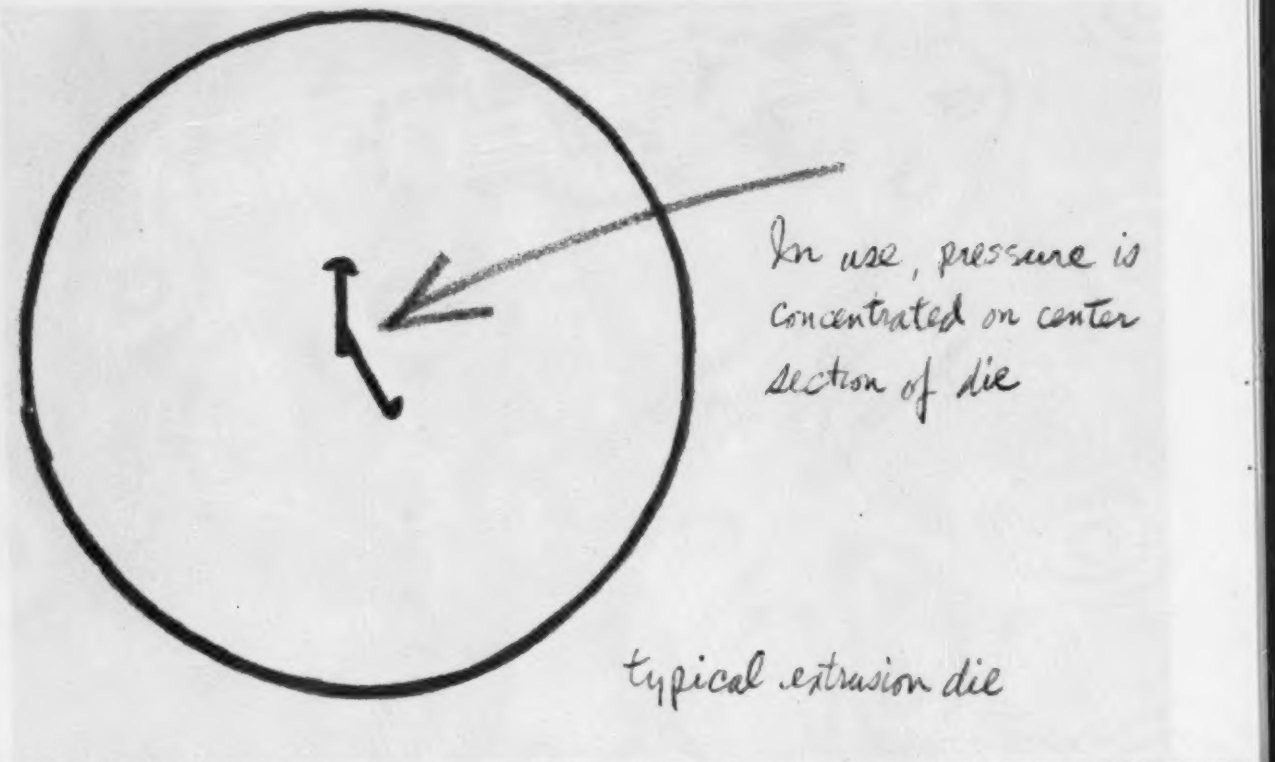
For Action: Contact our nearest District Sales Office or send a sample, drawing or description, estimated quantity, kind of metal required and other pertinent data to: The American Brass Company, French Small Tube Division, Waterbury 20, Conn.

ANACONDA®

SPECIAL-SHAPE TUBES

Made by The American Brass Company

**SPECIAL-SHAPE TUBES IN LONG LENGTHS OR CUT UP—
IN COPPER, BRASS, BRONZE, NICKEL SILVER, ALUMINUM**



MEL-TROL

Until now, it's never been possible to look at an alloy bar or disc and be sure its center is as sound as its surface. Sometimes centerline weakness won't show even in a cross section. But it *will* show in rejects, breakage, rapid wear. The extrusion die illustrated is just one example.

High alloy or high carbon steel bars and discs made by conventional steelmaking practice are subject to poor toughness and erratic properties at the core. The cause is inhomogeneity—segregation, porosity, weakness—that occurs in the ingot while it is freezing.

Composition of the steel, purity, pouring temperature and ingot mold design all affect core quality. Core defects cannot be entirely eliminated by rolling and processing of mill shapes. They remain in the core of the bar, and may vary from major defects such as internal cracks, porosity and center segregation to subtle differences in mechanical properties and service behavior between core and surface material which are virtually undetectable before machining or before a part fails in service.

The Mel-Trol process eliminates the problems of inhomogeneity by eliminating their causes.

Mel-Trol is an organized system of extra time, extra care, extra effort—perfecting the steelmaking process to its very greatest efficiency.

Quality control begins with scrap analysis, follows through the melt, casting the ingot, through rolling, annealing—all the mill processes that prepare Carpenter alloys for you—the user. Mel-Trol uses exclusive,

Flow and Fracture

*By EARL R. PARKER**

Today, designers and constructors of advanced machines and structures are often hampered by inadequate materials, a dilemma which can be solved only after acquiring knowledge about crystalline structure at an atomic level. Progress in this line has been sufficient to devise substantial improvements in creep resistance. A ductile ceramic also seems a fairly early possibility. (Q24, Q26, N general)

PRIOR TO ABOUT 1940, any equipment that could be designed could be built with existing materials. Since then, many machines and devices have been designed that cannot be built because of the lack of suitable constructional materials. Some examples of today's requirements are high-temperature semiconductors, structural materials high in strength and low in weight, and others that can withstand high tensile stresses at temperatures that would melt steel or the "superalloys".

Can the engineer rise to the challenge and produce the substances required by the atomic age? It appears that the answer must be "No", if past developmental methods and practices are followed. It is only necessary to review the progress made, for example, in gas turbine alloys. During the last 15 years millions and millions of dollars were spent on "high-temperature alloy development". To what avail? A few new alloys were formulated and marketed but the maximum operating temperature was barely raised 200° F. and at least half of this gain was due to better mechanical design and better quality control of the metallic parts.

I make so bold as to predict that lack of progress in this instance is in large part due to the same basic fault that retards progress in many other fields, namely, inadequate understanding of the basic physical processes which control the behavior of materials. Consequently, investigators were almost invariably forced to fall back on the empirical approach, trial and error – the same method used by metallurgists since prehistoric times.

Many of the advances in metallurgy for the last 150 years have been associated with chemical technology. Today, however, the situation is different. Metallurgy has reached the point where advancement depends upon our knowledge about solid-state physics. To cite a specific example, the transitor resulted from fundamental advances on the theoretical side; it produced a technological revolution in electronics. A similar example is the permanent magnet made of extremely fine magnetic powders, an "invention" due to theoretical advances which predicted from fundamental knowledge that such materials could actually exist. Clear-cut examples of this kind are limited in number at present but they are prototypes of those forthcoming within the next decade. Solid-state science will unquestionably play a major role in the *discovery* or *invention* of new materials.

* A digest of the Campbell Memorial Lecture, presented before the A.S.M. on Nov. 6, 1957. The lecturer is professor of metallurgy in University of California's department of engineering at Berkeley.

Another major contribution of solid-state science is an improved understanding of the behavior of existing materials, which will extend their use. While the sudden arrival of a new material is a dramatic event, tremendous technological advances may be expected to result merely from the systematic scientific analysis of materials and processes in current use. In fact, new materials and applications are most likely to occur as the byproducts of a deeper understanding of the behavior of old familiar metals, alloys and mixtures.

To appreciate the potential utility of solid-state science, it is necessary to remember that the properties of materials fall into two classes – those that are structure sensitive and those that are not. Since one of the metallurgist's functions is to control structure, he thus has potential control over one set of properties. About the other set, however, he can do nothing; he is powerless to change the elastic constants, density, specific heat, and heat of fusion or sublimation. On the other hand, tremendous variations are possible with ductility and strength.

I call upon the metallurgist to look forward into a new era of technology. In the decade following World War II, many new metals and metalloids became important. Germanium and high-purity silicon revolutionized the electronics industry; a whole new light-metal industry grew up around titanium; zirconium emerged from a laboratory curiosity to become a metal vital to the nuclear engineering program; uranium (almost unknown in 1940) and plutonium (an amazing man-made chemical element) formed the basis of atomic energy.

The big lesson to be learned from this roster of new metals is that a host of new materials, and many of them nonmetallic, is appearing on the scene. There are too many combinations of elements possible for us to investigate them all by trial and error methods. Even though actual test results will provide the background information necessary to select the new materials, intelligent application of basic principles is the only feasible means of attacking the problems ahead.

With this as a general introduction, perhaps necessary to an audience composed largely of men who are doing things with metals rather than inquiring into what makes them act the way they do, I should like to review in this Campbell Memorial Lecture for 1957 the concepts of flow and fracture that have slowly developed during the past two decades and to show how these concepts can lead to the development of new or improved materials as well as to provide a better understanding of the behavior of those now in commercial use.

Earl R. Parker, ⊕ Campbell Memorial Lecturer for 1957, is the author of more than 60 technical publications and a book entitled "Brittle Behavior of Engineering Structures". He has been a professor of metallurgy at University of California since 1945 and is vice-chairman of the Division of Mineral Technology. He received his metallurgical engineering degree from Colorado School of Mines in 1935 and was research metallurgist at the General Electric laboratories in Schenectady until 1944. Last year he was awarded the Mathewson Gold Medal of the A.I.M.E. for his research publications in that Society's journal.

Dislocations

Prior to the conception of the dislocation theory, slip was known to take place on certain crystal planes and always in the direction of closest atomic packing. Theoretical calculations indicated that the yield strength of metallic crystals should be on the order of 10% of the shear modulus. However, real crystals were known to yield at stresses of only a few pounds per square inch. This observed weakness could not be explained if the crystals were really perfect – as assumed. Prior to 1930 there had been some speculation that crystals usually were

imperfect and there was rather convincing X-ray evidence that this was so. If crystals actually contained flaws, then their weakness might be explained on the basis of the stress concentrations existing around the defects. It was this sort of logic that led to the dislocation theory in 1934 by Taylor and Orowan. Taylor even developed a mathematical theory based upon interaction of the stress fields surrounding dislocations to explain how work hardening occurred and why.

The dislocation theory was elaborated slowly during the first decade of its existence. It was generally accepted as a theoretically satisfactory tool but there was no direct experimental evidence to confirm its validity. Undaunted, the theorists moved ahead, and by the latter part of the 1940's they were able to predict that certain events *should* occur. For example, "screw dislocations" *should* cause rapid growth of crystals from the vapor or liquid phase at a degree of supersaturation that could only cause very slow growth of "perfect" crystals. Again, theoretically, "edge dislocations" of like sign *should* arrange themselves above one another on parallel slip planes to form a small-angle subgrain boundary and such a boundary *should* move when subjected to a shear stress. All of these predictions were confirmed by experiments in the early 1950's. During the intervening years, experimental techniques have improved at an almost unbelievable rate and today the modern electron microscope can watch individual dislocations move within metal crystals! Other experiments with transparent ionic crystals have further confirmed the existence of dislocations and the theoretical predictions of their behavior.

The newly developed experimental techniques and refined predictions of the theory have enabled us to understand how and why such phenomena occur as strain hardening, creep, yield point, solution hardening, precipitation hardening and grain size effects. Not quite matured but developing rapidly is an understanding of fracture phenomena, such as cleavage and ductile fracture, fatigue, intergranular cracking and stress-corrosion cracking.

Strain Hardening

What occurs within a metal to make it become harder and stronger when it is strained plastically? It now appears that the answer to this perennial question is at last in hand. Experiments with single metal crystals strained in simple shear have shown that dislocations moving through a crystal lattice under the action of a shear stress are occasionally retarded by barriers encountered in their march. Various kinds of imperfections or discontinuities can act as barriers – for example, other dislocations, grain or subboundaries, and particles of a second phase.

Experiments have shown that when slip occurs on only one slip plane and in a single direction, the resulting strain hardening is due entirely to entanglement of dislocations at barriers. Dislocations tend to loop around these barriers, much the same as a rubber band can be stretched around a post, but the trapped dislocations are retarded and the stress must be increased before flow can continue. Technically speaking, the trapped dislocations produce a "back stress" in opposition to the applied stress; the applied stress must increase if flow is to continue. One important cause of work hardening is this "back stress".

There seems to be only one other major contribution to work hardening, namely, that due to the combination of two dislocations originating on different slip systems. When two such dislocations meet, they combine to form a new dislocation having a slip vector* in a direction different from that of either of the reacting dislocations and often in a direction where the lattice is unreceptive to slip. Combined dislocations form lattice discontinuities which moving dislocations can only penetrate with extreme difficulty. Thus, when slip occurs on more than one slip system, new barriers to moving dislocations are continuously being generated during the flow process and this phenomenon contributes to strain hardening.

When a metal is deformed at room temperature and then reheated to successively higher temperatures, several changes occur to relieve the acquired state of strain. Dislocation loops that have expanded outward from their source and have been held up by barriers tend to collapse, gradually becoming smaller and finally disappearing back into the source from whence they came. This process happens rather easily and quickly. It has little effect upon the hardness or strength of the metal but reduces internal stresses substantially and improves the electrical conductivity.

A second process that occurs is the annihilation of dislocations by the combination of pairs of opposite sign. This process generally requires the movement of the dislocations in the direction

*The magnitude and direction of the lattice displacement caused by slip.

perpendicular to the slip plane — a process known as "climb", which involves the condensation of vacancies or extra atoms on the dislocation line. The climb process is diffusion-controlled and hence the rate of climb versus temperature follows an exponential relationship.

A third phenomenon contributing to recovery is the formation of a substructure due to the collection of like dislocations in boundary walls, usually forming on surfaces perpendicular to the slip plane. As theory predicted, such an array constitutes a low-energy configuration of dislocations. Climb is also involved in subboundary formation and so this formation is also diffusion-controlled.

Creep

Ever since the phenomenon of creep was first discovered, attempts have been made to describe it in mathematical language. The first expressions were merely empirical equations formulated to fit the experimental results. In the early 1940's attempts were first made to formulate mathematical theories that were based on a physical picture of the creep process — specifically, on the basis of reaction-rate theory. In these theories, an unspecified "flow unit" was presumed to move through the lattice but was unable to move from one position to another without the assistance of thermal fluctuations.

During the past five years it has become increasingly clear from theory and experiment that creep is controlled by dislocation climb which in turn is controlled by self-diffusion. The activation energies found for the creep of almost all metals coincide with those for self-diffusion. Furthermore, simple single-crystal experiments have shown that the dislocations stopped by barriers at low temperatures are only temporarily retarded at creep temperatures. X-ray evidence has shown clearly that dislocation climb and substructure formation are associated with high-temperature creep. Thus in recent years experiments have shown that the rate-controlling process is dislocation climb and climb is necessary to permit dislocations to move past the barriers that stopped them.

Most of the theories formulated to date have been based upon the assumption that the *source* had to be thermally activated or that the *movement* through the lattice required thermal activation. Since the rate-controlling step is the escape of dislocations at trapping barriers, any theory based on those assumptions cannot be correct. Only within the past two years has a reasonable theory been formulated with the assumption that climb is the rate-limiting step.

The shape of the creep curve has recently been explained and it is now possible to control the curve shape, changing it from its normal concave downward configuration to a straight line, or even reversing its direction of curvature. This can be done with simple procedures which produce subtle changes in the material's structure.

Solution Hardening

The concept of alloying to increase the strength of a metal originated during the Bronze Age. Exactly what happens within an alloy to make it harder and stronger than the base metal, however, is still a matter for speculation. It seems rather clear now that solution hardening is due to the interaction of solute atoms with dislocations. Just how and why these interactions occur is the problem. Experiments with steel have shown that the yield point (drop of beam in the tensile test) is due to dissolved carbon or nitrogen concentrated in dislocation walls or grain boundaries which stop the movement of dislocations. The shorter the distance between the pinned barriers, the higher the yield strength. It has been shown that the yield point of annealed medium-carbon structural steel can sometimes be increased by 25% without harm to other properties such as the Charpy V-notch transition temperature. The technique is to introduce a dislocation substructure within the ferrite grains and allow carbon or nitrogen to react with the dislocations in the sub-boundary network.

The mechanism of substitutional solution hardening has been more obscure. A number of theories have been advanced but none verified experimentally. Recent experiments with alloy single crystals indicate that the hardening process is like that for interstitial alloys — namely, it is due to the interaction of solute atoms with substructure boundaries. The evidence is clear that solution hardening is caused neither by the pinning or deactivation of the source, nor by retardation of dislocations as they move through the relatively perfect portions of the lattice.

Solution hardening has been shown to be structure sensitive, and so it is now clear that this phenomenon cannot be properly described by a simple general mathematical law.

Hardening in Two-Phase Systems

The cause of hardening in two-phase systems has not been elucidated to any significant extent principally because solution hardening has been

so puzzling. Plastic flow must still occur in a ductile matrix in which are dispersed hard brittle particles. Unless the flow and strain hardening processes that occur in a saturated solid solution (the matrix) could be clearly understood, it would obviously be impossible to understand how such a substance could flow when it contained a dispersed second phase. Now that an understanding of the mechanism of solution hardening seems to be at hand, one can attack the problem of plastic flow in a two-phase system with some assurance of success. This has not yet been done, however.

Fracture

There are a number of different kinds of fracture including cleavage, shear, fatigue, intergranular, and stress-corrosion. Fracture is known to be a two-stage process involving, first, nucleation of a crack, and second, growth of a crack. Theories describing growth processes are relatively simple to devise; indeed, a number have already been formulated. It is the crack nucleation that presents the real problem at present.

For example, how do dislocations act to form a crack nucleus in a ductile material failing by shear? Similar questions apply to all of the other types of fracture, and as yet there are no satisfactory answers. There is an encouraging note, however, because in current work a combination of theory and experiment is providing an understanding of how such crack nuclei can form in brittle cleavage fractures in steel at low temperatures. According to dislocation theory, groups of dislocations pile up at barriers such as grain boundaries and induce local tensile stresses which approach the theoretical cleavage strength of the material. Predictions based on this theory – for example, the effect of grain size – are in good agreement with experimental results, and it should not be very long before brittle cleavage behavior is well understood.

Recent work on the origin of fracture nuclei in fatigue has been very illuminating. Experiments have shown that, at least with some metals, cracks develop on the surface because flow occurs successively on two slip planes that intersect each other near a free surface. Periodic removal of the surface layers prolonged fatigue life indefinitely! In other experiments, single crystals of zinc were subjected to reversed cycles of simple shear. In a room-temperature test, with a strain amplitude of 1%, the crystal was unharmed even after three million cycles (6,000,000% accumulated plastic strain).

Thus, some of the conditions necessary to avoid or to cause fatigue have been disclosed. It seems that an understanding of the basic processes leading to fatigue will soon be forthcoming.

In regard to ductile shear-type fractures and stress-corrosion cracking, the theoretical picture is still vague and unsatisfactory. Both of these involve nucleation and growth of cracks but at present there is no acceptable picture of either how cracks get started or how they grow.

Nonmetallic Crystals

From the accumulated knowledge about flow and fracture processes, it seemed reasonable to conclude that certain nonmetallic materials, particularly cubic ionic crystals, should exhibit plastic properties like those normally associated with metals. Earlier work on sodium chloride and on silver chloride strongly supported this conclusion. A rather large fundamental program has recently been initiated to investigate the possibility of making certain refractory ceramic materials which would be ductile at room temperature. The early results have been encouraging. Many cubic ionic crystals have been tested and to date all have been found to be ductile or could be made so at 70° F.

The most encouraging results of all are those obtained with magnesium oxide. Single crystals could be bent through substantial angles without fracture at room temperature. Surface elongations up to 20% have been obtained in some of the bend tests. There is a good chance that a number of useful ductile ceramic materials will be developed within the next few years.

Conclusion

Perhaps enough has been said – even though in rather general terms – to indicate to the "practical" man that the "scientist" is working along lines which will build the foundations for new and useful materials of construction with unexampled properties.

Perhaps there is no reason to argue the point. A little reflection will indicate that the Edisonian "try everything" program is hopelessly inadequate in this day of rapid advance. The chance that such an approach would be worth what it costs is practically zero. I can assure any doubters that the achievements of the solid-state physicists during the last 15 years have been exceedingly encouraging, and I hope that this brief account of modern concepts of flow and fracture has illustrated that one point. We are at last learning something about why metals are so weak!

Direct Chill Casting of Large Aluminum Ingots

By A. T. TAYLOR
D. H. THOMPSON
*and J. J. WEGNER**

Interrupted quenching is incorporated in the D.C. process to produce sound castings in sizes large enough to provide billets for huge forging and extrusion presses. A simple air blast device interrupts the flow of quenching water. (C5, N12; Al, 5-9)

MANY OF THE large presses which have been constructed for the heavy press program of the United States Air Force are now in production. The construction and operation of these massive extrusion and forging presses has aroused wide interest throughout the metal-producing and metal-consuming industries. This interest has been concerned predominantly with the construction features and operating characteristics of the presses. Often overlooked, however, is the extensive effort of the aluminum industry to establish the production techniques which will supply the outsize aluminum alloy billets required to feed these presses.

At the start of the heavy press program, the largest aluminum process ingots of high-strength alloy cast on a commercial basis had a maximum transverse dimension of 12 to 14 in. It was foreseen that many of the forgings and extrusions to be made in the new mammoth presses would require considerably larger ingots. Unsolved problems associated with the casting of large ingots, therefore, presented a serious obstacle to the success of the program. Desirable goals for the aluminum industry would be the production of high-quality 32-in. diameter ingots in 7075 alloy and 2014 alloy.

Two years of development efforts by the Kaiser Aluminum & Chemical Corp. culminated in 1952 with the announcement that sound 32-in. diameter process ingots could be cast in 7075 alloy using a modification of the direct chill process. This modification employs the concept of an interrupted quench during the casting process. The interrupted quench reduces the rate and magnitude of stress build-up within the ingot, and thereby substantially eliminates the cracking problems which had previously made the routine casting of massive

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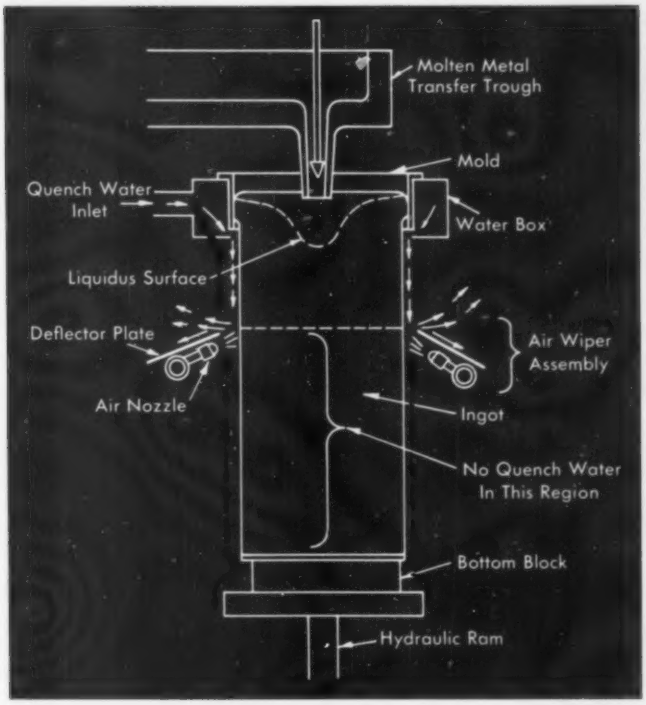


Fig. 1 – Direct Chill Casting Unit. Black arrows show course of quenching water in conventional process. White arrows show interruption of quench by air wiper

aluminum ingot in high-strength alloys an impossibility.

D.C. Casting Process

The D.C. (direct chill) casting process is the method used today to produce essentially all of the commercial aluminum ingots for subsequent processing by rolling, forging and extrusion. Developed by W. T. Ennor prior to 1940, the process has the advantage of producing a fine-grained structure with minimum segregation. High production rates are obtainable, and the process is adaptable to semicontinuous or continuous production. In a conventional D.C. casting unit the principal parts, as shown in Fig. 1, are a water-cooled mold open at both ends, a bottom block with lowering mechanism, and provisions for projecting quench water directly on the ingot periphery during casting.

To start the cast, the mold is closed at the lower end by a bottom block and molten metal is poured into this cavity. When the metal has solidified sufficiently to form a shell, the bottom block and embryo ingot are lowered at a controlled rate and direct chill casting is in process. The heat contained in the molten metal, which is continuously added to the mold, is extracted by the mold cooling water, and most particularly, by the quenching action of the water sprays which impinge directly upon the ingot and flow downward over the entire ingot surface, as shown by the black arrows in Fig. 1.

Influence of Aluminum Alloy

The problems associated with D.C. casting have to do with both the alloy being cast, and the shape and size of the ingot cross section. Before 1952 the routine casting of process ingots of large cross section was impractical in stress-sensitive aluminum alloys – for example 7075 alloy. In this type of alloy the principal obstacles to the production of sound ingots are the wide temperature range of solidification and the tendency toward hot shortness.

Experience has shown that 7075 alloy, which has one of the widest solidification ranges, is the most difficult alloy to cast into sound process ingots. It is commonly considered that if a sound ingot of a particular shape and size can be cast in 7075 alloy, it is castable in other alloys commonly produced in this form.

Influence of Ingot Section Size

Rectangular ingots, intended for rolling into sheet and plate, have been cast in sections 12 in. thick and 48 in. wide, and individual ingots may weigh 6000 lb., although the weight depends on the capacity of the metal supply and the ingot length. Round and square 7075 aluminum alloy ingots with a principal transverse dimension much over 12 in. have not been cast until recently, although sound 2024 alloy ingots have been cast in sections as large as 16 in. in diameter. Other major aluminum producers have reported moderately successful casting of 32-in. diameter ingots in 2014 alloy but no details are available regarding the quality of the ingots produced.

The question then arises – what is a large ingot? The answer is related to the size and shape of the section and to the particular aluminum alloy being cast. In 7075 alloy, any ingot with the shortest transverse dimension greater

than about 12 in. is generally termed a "large" ingot. From the standpoint of tendency to crack, round ingots are more difficult to cast than rectangular ingots of equivalent cross section.

During D.C. casting, the thermal contraction of the metal generates a complex stress pattern within the ingot, which is a function of the ingot size and shape (round, square or rectangular). The larger the ingot – that is, the greater the transverse dimensions – the larger are the stresses. The stress pattern will also be affected by casting variables such as the ingot lowering rate and the flow rate of the quench water.

As the ingot lengthens, the stress pattern at a particular transverse location changes continuously as a result of the progressive contraction of the metal due to continuous application of the quench water. Unit stresses increase continuously. At the same time, however, the metal at this transverse location becomes stronger as its temperature decreases. When, at any point, the unit stress exceeds the ultimate strength of the metal, the ingot cracks.

When casting 7075 alloy ingots, industrial experience has established that the dividing line at which the generated stress frequently exceeds the strength of the metal occurs in ingots which have a shortest transverse dimension greater than 12 to 14 in. Thus, using the conventional D.C. casting process, a sound 11 × 44-in. rectangular ingot can be cast in 7075 alloy, but the casting of a 15 × 60-in. rectangular ingot in the same alloy would be uneconomic due to excessive cracking.

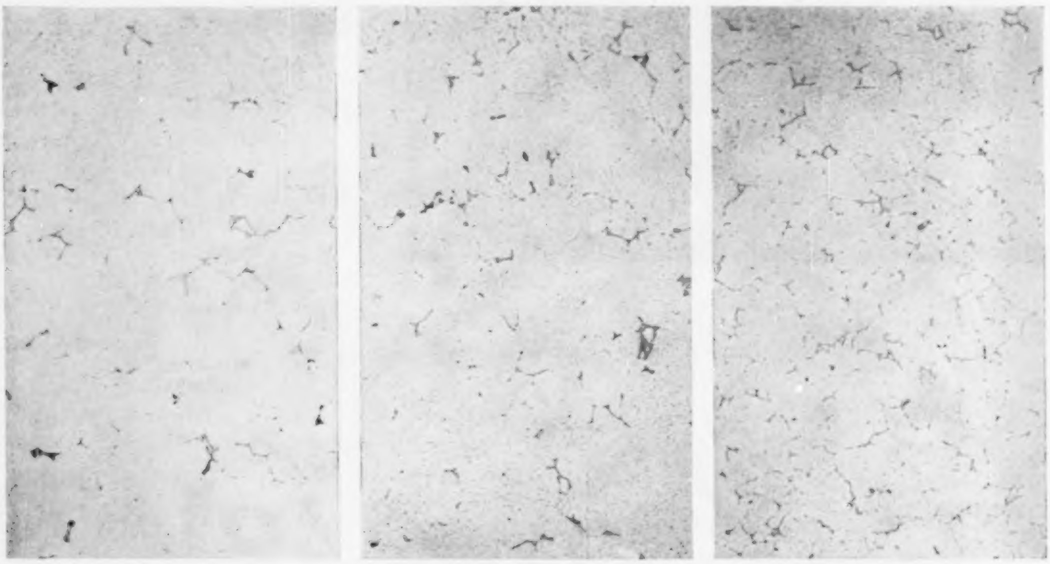


Fig. 2 – Samples From Transverse Section of 32-In. Diameter 7075 Aluminum Alloy Ingot. From left, center of ingot, midradius and edge. Ingot was given homogenizing treatment, and intergranular constituents reprecipitate as ingot is cooled. Etched in 0.5% HF. 100 ×

Development of the Air Wiper

The solution to the cracking problem was basically the use of interrupted quenching during the casting process. It was realized that there was no practical method to increase the strength of the metal as it left the mold, but, by using an interrupted quench, it might be possible to reduce the build-up of internal stress caused by thermal contraction of the metal as it cooled. This was done by means of an air blast. As shown in Fig. 1, the nozzle assembly directs the air blast toward the ingot surface, thereby "wiping" it free of quench water.

In the Kaiser research department this technique was first shown to be practical for the production of high-quality 18-in. square ingots in 7075 alloy. Eventually the original goal was attained – sound 32-in. diameter and 24-in. square ingots of 7075, 2024 and 2014 alloys.

Concurrent with this work, other development programs were overcoming specific problems which adversely affect the quality of aluminum ingots. Gas porosity and inclusions were mate-

Fig. 3 – A 32-In. Diameter 7075 Alloy Ingot Immediately After Casting

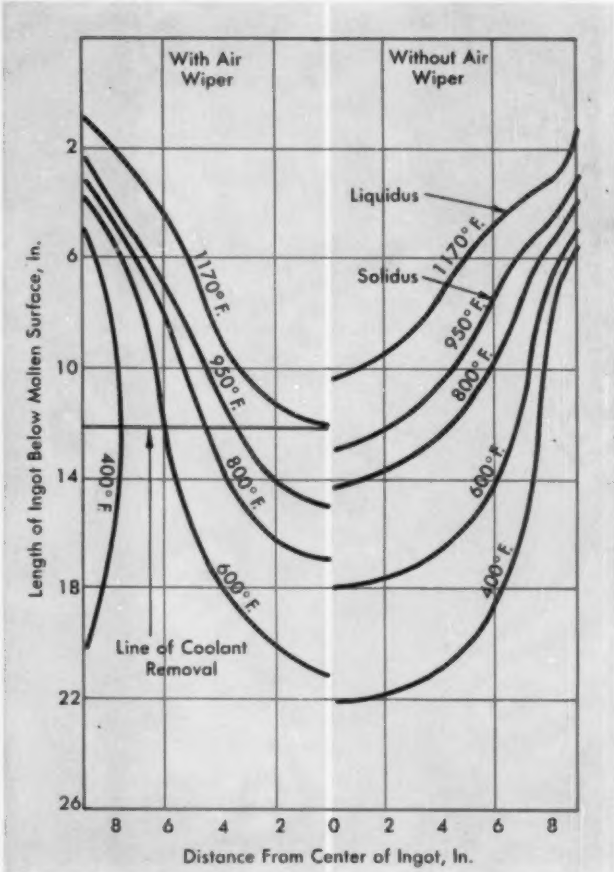
rially reduced or eliminated by improved metal cleaning and degassing practices. Since these procedures are applicable to the casting of all ingot sizes, the improvement in the quality of both ingot and fabricated product can be considered a major achievement by itself.

Micrographs of as-cast sections from 32-in. diameter 7075 alloy ingots are shown in Fig. 2. The uniform grain size and absence of porosity are evident. Figure 3 shows a 32-in. diameter 7075 alloy ingot immediately after casting. The over-all quality is excellent.

Air Wiper Design

The clearance between the ingot emerging from the mold and the air nozzles should be from ⅜ in. to 1½ in. Larger distances would obviously require more air to remove water

Fig. 4 – Isotherms in Top Portion of 18-In. Square 2014 Alloy Ingots Cast Under Identical Conditions Except Use of the Air Wiper



completely and smaller distances might result in interference between the air nozzle assembly (air wiper) and the descending ingot. The elevation angle of the air nozzles with respect to a horizontal plane normal to the ingot face should be between 20 and 50°.

The major variable involved is the length of ingot sprayed with water before wiping. This distance is related to the minimum transverse dimension of the ingot, varying between one eighth and one half. Thus, for a 32-in. diameter ingot, length of coolant application is 4 to 16 in. It is somewhat dependent upon the particular alloy type – less stress-sensitive alloys can withstand a more severe quench.

Interrupted quenching also has other favorable aspects. A major problem in the casting of square or rectangular ingots has been cracking at the corners as a consequence of stress build-up resulting from overchilling. At corner locations, the metal is cooled from two surfaces, whereas the metal midway along the face of the ingot is predominantly quenched from one direction only.

To overcome this corner overchilling defect the length of coolant application at the ingot corners is reduced by proper vertical positioning of the air wiper nozzles. As a result the corners are quenched less severely and corner cracking is eliminated.

Influence on Molten Metal Crater

To avoid shrinkage cracks it is generally believed that a relatively flat, shallow crater of molten metal is desirable. Temperature measurements made during the casting of an ingot indicated that the interrupted quench tends to produce a deeper crater. This is illustrated in Fig. 4 which shows the isotherms in the top portion of two 18-in. square, 2014 alloy ingots. Casting conditions were identical, except for quenching – continuous in the right-hand plot and interrupted at left. These data indicate that the internal conditions produced by the use of the wiper are conducive to a deeper crater and a stronger tendency toward shrinkage porosity. However, it has been possible to adjust other casting conditions to compensate for this tendency and produce sound ingots.

It is entirely possible that ingots with a minimum transverse dimension much larger than 32 in. can be cast using the principle of the interrupted quench. However, the commercial need for larger aluminum process ingots has not appeared to date.

Other means of reducing the quenching rate of ingots can be visualized as alternatives to a water removal system. For the present, however, this method appears most advantageous from the standpoint of versatility and economy. Consequently, the development of this modification of the classic direct chill process stands as a major advance in the field of casting aluminum process ingots.

Modern Heat Treatment Facilities

*By DANIEL A. TULLOCK, JR.**

Heat treating equipment for hardening and coloring high-strength studs and bolts without damage to threads is installed in new building, a model of cleanliness, ventilation, light and elbow-room in the basement. (J26n, J29, W27g, W12r, 1-2; ST)

IN 1955, when we decided to improve the heat treating facilities at the Holo-Krome Screw Corp. plant in Hartford, Conn., we had many objectives. To understand these objectives to be incorporated in any new installation, we should first describe our old methods. Although they resulted in a product of good quality, the conditions in the department left much to be desired.

For more than 25 years, we had been hardening socket screws in continuous furnaces of both the conveyer and reciprocating-hearth types. After the oil quench, the parts were centrifuged to remove the excess oil and then placed in batch tempering units of the rotary type. When the tempering cycle had been completed, the parts were again oil quenched and centrifuged before sending them to the packaging department.

Cap screws, set screws, socket-headed bolts and the like, heat treated in this manner, were delivered with a uniform black color which, in our industry, is an important factor. This, then, was a desirable result. Small nicks on the threads, accumulated during the nine times the parts were dropped in the process, plus the slow tumble in the rotary tempering furnace, were a constant source of trouble. These nicks, therefore, had to be eliminated or certainly minimized in any new installation. At the same time, a clean black finish had to be maintained.

It was obvious that the way to eliminate nicking would be to reduce handling. This could be done through automation, but in our opinion only through controlled automation. We therefore presented our problem to eight manufacturers of continuous heat treating equipment. In addition to data as to production rates, hardness and physical properties of the product — especially the surface layers — we not only told them the parts had to be a good, clean black, but also that the nicking had to be eliminated. Actually, we gave them all the latitude possible, for we told them we would be interested in any "dream unit" they might have, either on the drawing board or in their minds. Frankly, we were disappointed in the results, for each of the manufacturers, with one exception, quoted on the same type of continuous setup they have been manufacturing for the last 10 to 20 years. The exception was the American Gas Furnace Co. of Elizabeth, N. J., whose unit we ultimately purchased.

* Chief Metallurgist, Holo-Krome Screw Corp., Hartford, Conn.

Continuous Unit

Basically, this continuous hardening and tempering unit (shown in Fig. 1) consists of one of their No. 242 reciprocating-hearth furnaces in line with a new, and we believe quite novel, conveyer type of tempering unit. As originally installed, the charging end of the unit at the left of the illustration was equipped with a vibrating feed mechanism made by the Syntron Co. We have many such units in our plant, but for this application we replaced the mechanism with a 5-ft. shelf extending in front of the muffle hearth, supported on rollers, from which the work automatically works forward to the reciprocating hearth of the furnace. After being gently poured or placed on this muffle extension, the small parts proceed through the furnace at the proper rate for their size, and slide down a sealed chute pitched at 60° into the quench oil where they come to rest on a mesh conveyer.

Through this stage of the process, we insure an unchanged carbon content at the surface by introducing an atmosphere which is essentially nitrogen with low percentages of hydrogen and carbon monoxide. This is an exothermic gas from which carbon dioxide and water vapor have been removed. The nitrogen generator, manufactured by the Gas Atmospheres Corp. of Cleveland, is equipped with a Cambridge hydrogen analyzer which records, controls and thus guarantees gas with constant chemistry.

The work, on being quenched, is raised on a flight conveyer to a chute where it again slides down onto the belt conveyer of the tempering unit. We feel that the American Gas Furnace Co. really came up with something when they designed this unit. The belt travels through a completely enclosed muffle; combustion gases never come in contact with the work. The belt travels through the muffle to the discharge end where it passes over an alloy roller, down a 60° slope, around another roller and then through a seal leg into a shallow tank full of soluble oil. (Naturally, the work leaves the belt at the end of the 60° slope.) This seal of soluble oil at the far end leaves only one opening to the atmosphere, namely the one at the charging end, and here, as can be seen in Fig. 1, the flight conveyer with its charge enters a hood extending downward to below the level of the furnace's hearth. Since oil is carried on the parts, the vaporizing oil creates a positive furnace pressure and thus no air infiltrates. The parts are therefore tempered in an oil vapor atmosphere and the resultant black finish is excellent.

After being tempered, the parts slide into a tank of soluble oil, are cooled and then conveyed

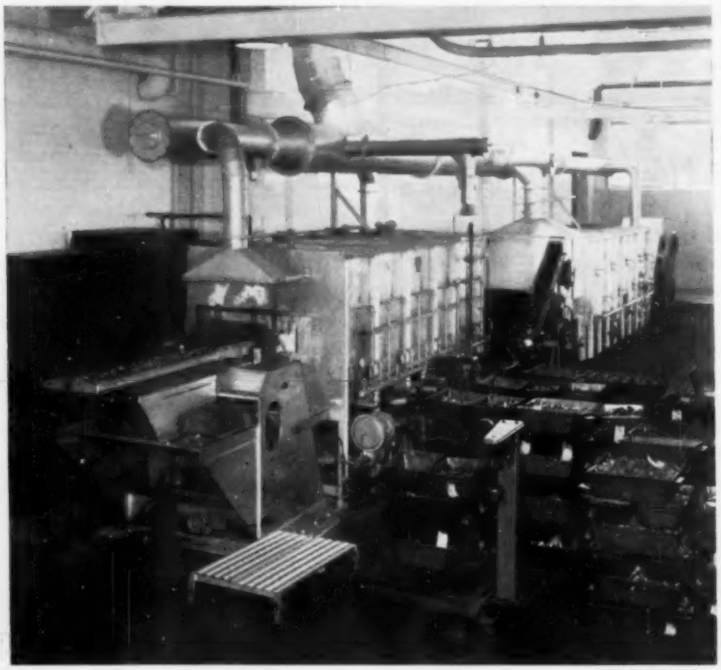


Fig. 1 — Hardening Furnace Has Long Prolongation of Reciprocating Hearth for Charging Small Work. Tempering furnace at rear operates with atmosphere of vaporized quenching oil. All handling equipment is especially designed to prevent severe impact which would mar precise finish

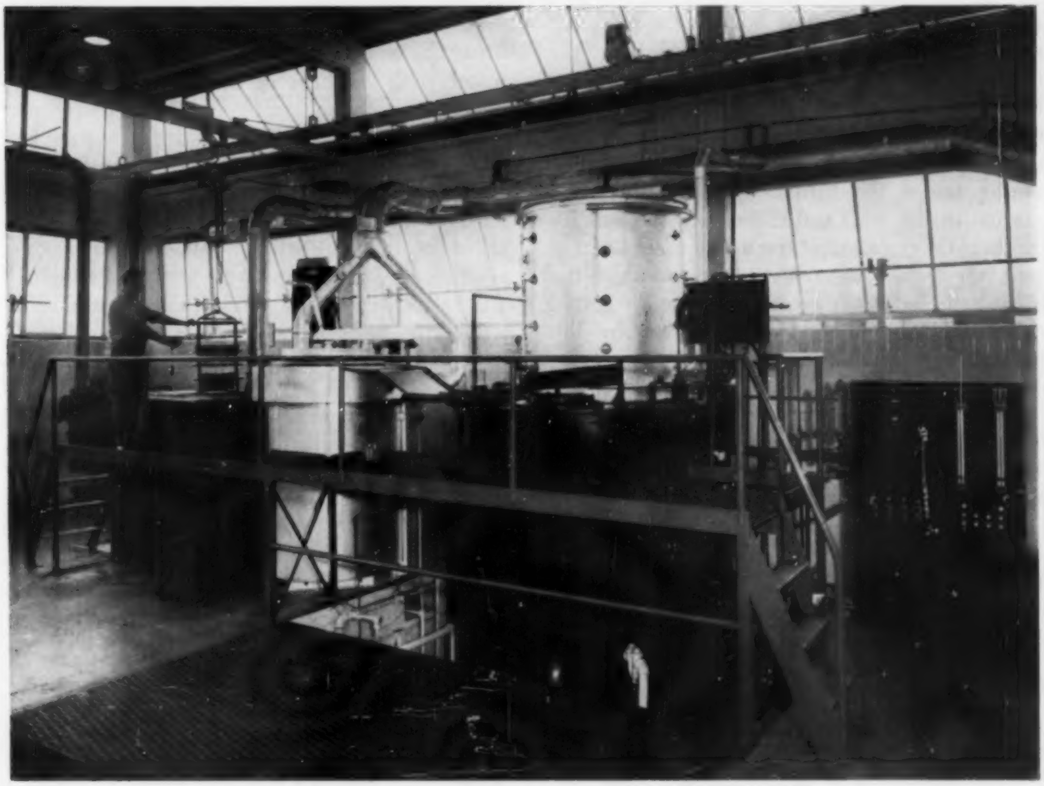


Fig. 2 – Large Screws, Studs and Bolts Are Jigged. Hardening furnace at right has entrance vestibule in front (dark portion). Fixture is lowered on elevator, moved toward rear, lifted into heating chamber (light portion above), lowered into quenching bath in bottom of unit, and then retraces steps to outside. Quenching oil remaining in socketed heads is sucked out by vacuum cleaner before fixture is put into drawing furnace (light-colored unit in center)

to a Syntron mechanism which removes the excess oil and deposits the parts in tote pans. When this new furnace was started up we used quench oil in this tank but soon found that the carry-out completely saturated the packages. This was undesirable for obvious reasons, yet we did not want to go back to a centrifuge; a vibrator did not remove sufficient oil. The decision was made to convert the tank so it could efficiently use soluble oil. It was therefore insulated and covered. In order to heat the oil to 160° F. we utilize a glass-lined domestic hot water heater and pump the soluble oil through the tank. It works very well, although it takes 36 hr. to bring the temperature up. This is of little consequence since we merely let the heater run over the week end. We are using a high-grade, rust inhibited soluble oil compounded for us by the Swift Industrial Chemical Co. of Canton, Conn. The feeling here is that if a soluble oil is needed, we should use one that will pass on some benefit to the customer – which, in this instance, is a product that will resist rusting.

Unit for Larger Work

Our new heat treating department also had a definite need for a furnace to handle large-diameter and long lengths of cap screws. For the past several years, sales of these larger and longer screws have increased tremendously. We had previously sent the parts to a commercial heat treater, but this sometimes delayed deliveries, and now and then lots had to be rehardened.

Our choice was once again a unit especially designed and built by the American Gas Furnace Co. The furnace is the right hand unit in Fig. 2. The parts are suspended by their heads on alloy plates which in turn are supported on a rack. The operator and small overhead crane are handling one such rack with 1½-in. diameter cap screws in it. This rack would be transferred to the top of the unit at front right of Fig. 2,

lowered through the trap door on the top front of the forward section (the dark tank) to the platform of a hydraulic elevator. The elevator lowers its load to the oil level, which is at the trap (white piping) shown at the front of the unit at about floor level. The load is then swung under the furnace proper (the white portion to the rear) and raised into the bell for the heating cycle. After the appropriate heating time, the load is lowered straight down into the oil quench, then swung over under the exit hatch, raised by the elevator, and removed by the workman. The entire operation is done under atmosphere.

As these socket screws are removed from the hardening unit, each socket is filled with oil. The volume thus entrapped is considerable. How to remove this oil before tempering in our Lanly pit-type recirculating air furnace was a problem which was quite readily solved with a Tornado vacuum cleaner. Passing the nozzle over the heads of the screws quite effectively sucks out all of it.

A Clean, Light Working Place

So much for the new equipment installed in the new heat treating department at Holo-Krome. We had something other than product improvement in mind when all this was done. President W. C. Stauble feels that the worker is the most important consideration in the plant. The machines don't count for much without people to operate them efficiently. He therefore believes that everything should be done to lighten their tasks and improve their working environment, making it as pleasant as possible. This was a primary aim in the new addition to the heat treating department.

The walls in the new area are a light grey ceramic tile. The ceiling and mono-rails are painted yellow. This new area is about 6 ft. higher than the adjacent manufacturing buildings. Thus, the whole roof in this area is, in effect, a monitor with windows on all four sides. (One of the window openers can be seen in Fig. 2 above the pit hardening furnace.) On the lower level, there are windows on only two sides. All of them run the entire length of the room and each section is operated by one motor. During the very hot summer of 1956, this area was as pleasant to work in as any section of the factory.

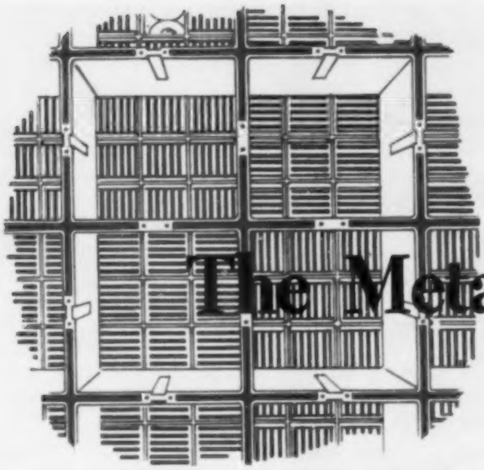
In our older installations, the pit areas around the quench tanks were just a little larger than the tanks themselves. This resulted in almost impossible conditions for maintenance and repair men. In the new addition, the pit is approximately half the area of the room and is 7 ft. deep. The quench tanks and furnace sections of the continuous line in Fig. 1 are supported by I-beams with steel grill-work floors around them. Blowers, pumps, and piping are all suspended from the same floor beams. Thus a man can stand naturally in the pit and work on any of the equipment. An additional advantage of hanging all the auxiliary equipment from the ironwork is that the pit floor can be mopped and hosed down. Pit walls and floor are also painted yellow. This pit is large enough to accommodate a second continuous line parallel to this first unit.

The storage tank for quench oil is located horizontally under the floor with a connection outside the building for filling from a tank wagon. Actually, we operate with this 5000-gallon tank and a 2000-gallon sump tank (the latter also located under the floor). Both tank-ends protrude into the pit 3 ft. with all piping connections on this end and a removable manhole on top. The main circulating pump and a stand-by pump are actually below the sump tank; therefore the suction side is always under pressure, which avoids all priming problems.

The oil is pumped from the sump through a Niagara evaporative cooler to the discharge chute of each hardening furnace. Each quench tank has an overflow weir at the end and thus the oil returns to the sump by gravity. When the oil level in the sump drops, due to dragout from the quench tanks, we merely start a small transfer pump and bring oil from the main storage tank to the sump tank. If the operator forgets to stop the pump, it will automatically stop when a pre-set level is reached. If it were necessary to empty a tank in an emergency, proper valving permits the main large-capacity circulating pump to transfer oil from the sump to the main storage tank.

Perhaps it should also be pointed out that the units shown in both illustrations are in operation. Because of the efficiency of the exhaust system installed on the equipment, there is never a wisp of smoke in the room even though smoke is really being produced, especially in the continuous tempering unit.

Thus the task set two years ago has been accomplished. We have given the workers a clean, healthful place to work in, the customer has benefited by getting a better product, and Holo-Krome has benefited by producing a better product at a lower cost per pound.



The Metallurgy of EBWR

*By KARL F. SMITH**

Development of the first experimental boiling water reactor created several metallurgical problems not previously encountered in atomic energy utilization. In finding solutions, Argonne National Laboratory developed new alloys and new fabricating techniques. (W11p, T11, 17-7; U, Zr, ST, SS)

THE ARGONNE NATIONAL LABORATORY "went on" atomic power in December 1956. At that time, the experimental boiling water reactor reached full power level at the site of the laboratory, located near Lemont, Ill.

The plant produces 5000 kw. of electricity, which is enough to provide the laboratory with its own power requirements and to show that larger power plants can be built using the principle of steam generation within the reactor itself. In addition to this simplification, in which heat exchangers are eliminated, a bonus advantage of increased safety accrues from its self-regulatory nature. In EBWR, generation of too much steam automatically reduces activity of the reactor by reducing the amount of moderation in its core.

EBWR uses "light", or ordinary water in its operation, although future plans include some tests with heavy water. Water circulates in a closed cycle by gravity. After leaving the pressure vessel which houses the reactor, steam goes to a conventional steam purifier and then to the turbine, after which it is returned to the reactor as water through a condenser. A continuously operating ion-exchange systems keeps the water pure and to the right degree of alkalinity.

*Assistant Director, Metallurgy Div., Argonne National Laboratory, Lemont, Ill.

Metallurgical Problems

Unusual conditions of irradiation and corrosion combine, as in other reactor plants, to present metallurgical problems. In turn, usual materials developed to meet these requirements result in further problems associated with the production, fabrication, and utilization of the new materials.

EBWR employs slightly enriched uranium (1.4% U^{235}) in the fuel elements. Metallurgically, the degree of enrichment with an isotope is not too important, because the mechanical and thermal properties are the same for both. Differences in technique of handling arise from the degree of care necessary to conserve the rarer isotope and to keep its dust out of the surrounding atmosphere during operations because of its greater health hazard.

The fact that uranium needs to be used at all in reactor fuel elements is unfortunate. Like some people, uranium is difficult to live with, and difficult to be without. When used as plain alpha-rolled uranium, the heating and quenching effect on a microscopic scale produced by the neutrons in a reactor causes it to grow, warp, and squirm, so that the shape of the fuel element would soon be so distorted as to bear little resemblance to its original shape. Heat removal under these conditions would become inefficient

and spotty in the core assembly, allowing some parts to overheat and fail rapidly by melting or rupture of their protective cladding.

Beta quenching of uranium from the range 660 to 770° C. (1220 to 1420° F.) results in a more stable structure, but some residual instability plus grain coarsening effect leave this metal considerably short of being a completely desirable fuel material.

Another facet of the problem, that of corrosion, enters into the selection of alloys for the fuel elements. The EBWR was not designed to boil at atmospheric pressure, but at 600 psi., at which the associated temperatures are highly corrossive to many metals. The Zircaloy-2 cladding for the fuel element material will withstand these conditions, but if a small rupture should appear in the cladding, and if the fuel material were unalloyed uranium, the latter would rapidly corrode and be lost out of the small fissure. Uranium itself has very low corrosion resistance to pressurized water. The water would then become grossly contaminated with fission products of uranium, and the fuel element would be progressively destroyed. It was therefore necessary to pursue the additional goal of increased corrosion resistance in the search for a suitable alloy for the fuel material, so that at least a second line of defense could be set up against that eventuality.

In the search for alloying agents that would provide stability toward irradiation and better resistance to corrosion, the tenary alloys with zirconium and columbium * eventually survived an elimination contest and showed some promise.

The uranium-base alloy with 5% zirconium and 1½% columbium, when quenched from the gamma phase, does not retain gamma, but forms an acicular alpha structure, similar in appearance to martensite in steel. The structure is quite corrosion resistant to high-temperature water. However, tests in the materials testing reactor at the National Reactor Testing Station in Idaho have shown unsatisfactory results under irradiation for this particular structure.

When this same alloy is isothermally transformed in the temperature range 630 to 650° C., the resulting structure becomes alpha plus gamma, which has been shown to be quite stable under irradiation, but of limited corrosion resistance. That is, the corrosion resistance is better than that of unalloyed uranium, but not as good as the gamma-quenched structure.

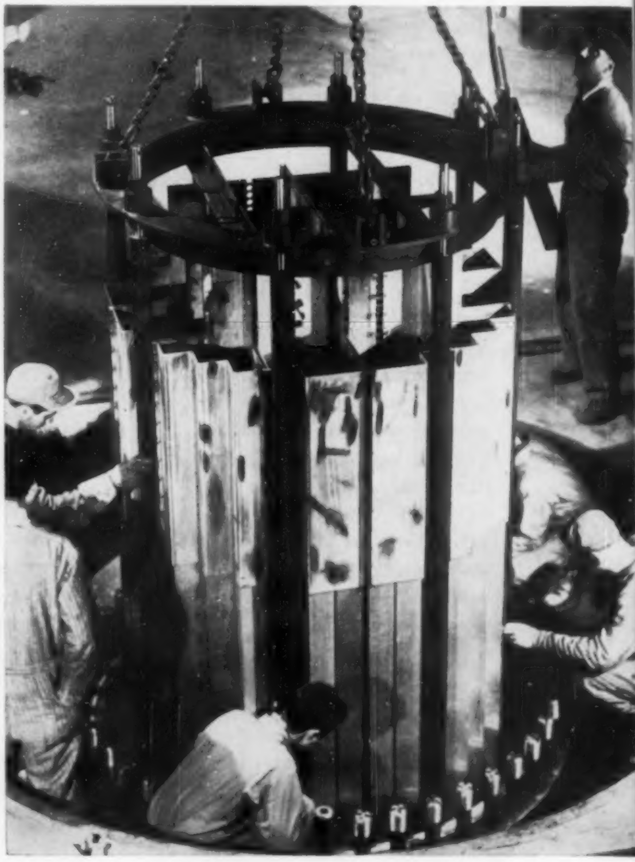
*Referred to as niobium by chemists.

In an effort to have our pie and eat it too, compromises were tried in heat treatments, including the use of a gamma quench followed by an isothermal treatment. All these artifices were unsuccessful. Accordingly, the decision was made in favor of the material of greater irradiation stability, despite its only moderate corrosion resistance. As a consolation prize the rolling characteristics of the alloy turned out to be more compatible with the Zircaloy-2 cladding than were those of unalloyed uranium.

Fabrication of Fuel Elements

Following selection of the fuel alloy it was next necessary to resolve fabrication variables. Reactor designers specify thickness of cladding in accordance with the requirements of physics and the necessities of mechanical strength at service temperatures. A given limit on the ratio of structural material to fuel material, made necessary by neutron economy, sets an upper

Fig. 1 – Core Shell Is Lowered Into Pressure Vessel



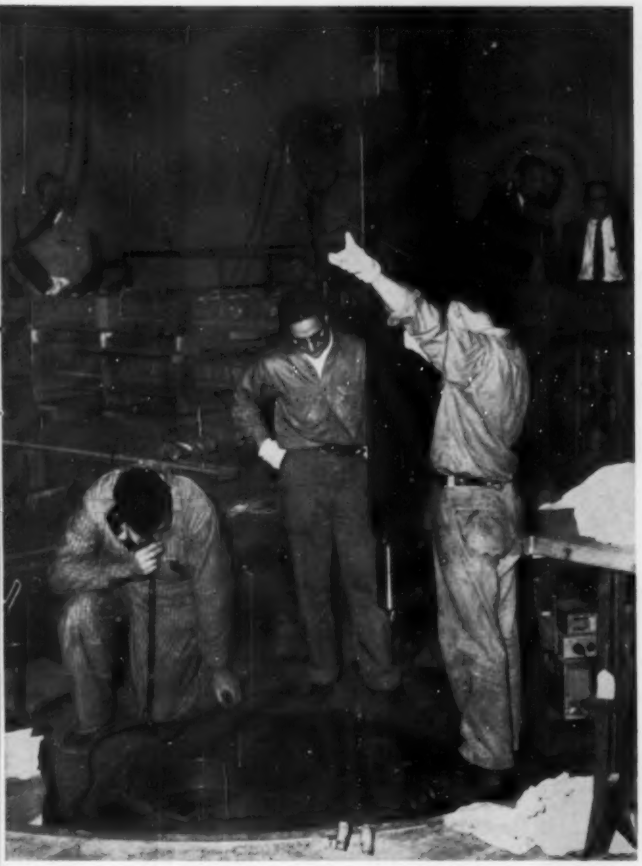


Fig. 2 – The Core Shell, Loaded With the Fuel Element Subassemblies, Is Put in Place. To prevent criticality, the core assembly must be made with the control materials in position

limit to the thickness of cladding which can be depended on to restrict a tendency to internal movement in the fuel material.

Translated to the fabrication process, this means that plate rolling tolerances must be so close that they approximate machining tolerances. For example, if the rolling temperature falls outside a certain narrow range, the core alloy tends to deform more or less easily than the cladding material, resulting in a disproportion of thickness which cannot be compensated for by machining, because of the thin layer of cladding involved. Furthermore, an optimum reduction sequence must be built into the mill by automatic means to insure uniform treatment for each plate. By radiographing each rolled plate, the core must be located with sufficient precision to finish machine the sides and ends.

Each plate was inspected for quality of bond between cladding and core by an ultrasonic recording method specially developed for the purpose. In addition, gross inclusions and porosity in the metal were readily spotted by this technique, a similar routine being applied to the original billets as well as to the finished plates.

An automatic welding device was designed and constructed for fastening six finished plates together, parallel to one another, in the manufacture of a subassembly for the core of the reactor. The number of these subassemblies necessary, together with the requirement of uniformity, made hand welding out of the question. By mechanical positioning, each weld which joined the flat side of a Zircaloy-2 side plate to the edge of a fuel element by the arc-spot method, was made according to a preset program of timing and current. The "arc-spot" method of welding plates into position works from the outside of the flat plates with fusion extending inward to the edge of the active plate. Spots are made, one at a time, with three electrodes on a carriage which contact consecutively and then move to a second lateral position before shifting to the next longitudinal position. By this arrangement, plates 1, 3 and 5 are welded in place and then the carriage shifts to weld plates 2, 4 and 6.

Predetermined value of the current was high as the arc was struck. This was followed by a reduction to about half current value to preheat the workpiece. At a certain stage the current again abruptly increased while the weld was made; then the arc was broken. With this machine approximately three subassemblies per hr. were manufactured from the fuel plates.

The Pressure Vessel

The pressure vessel of EBWR is 84-in. ID, weighs about 60 tons with internals in place, and is designed to withstand 800 psi.

Strength of the vessel is provided by the use of SA-212 fine-grained steel. This is a boiler steel with 65,000 to 70,000 psi. tensile strength, 35,000 psi. minimum yield strength and minimum elongation of 21%. Maximum composition limits of the steel are: carbon 0.28%, manganese 0.90%, phosphorus 0.035%, and sulphur 0.15 to 0.30%. All parts of the interior which are exposed to hot water or steam are clad with Type 304 stainless steel, because of its good corrosion resistance.

Neutron irradiation doesn't affect steel to any great extent. What it does do is harden it some, raise its tensile strength a little, lower its elonga-

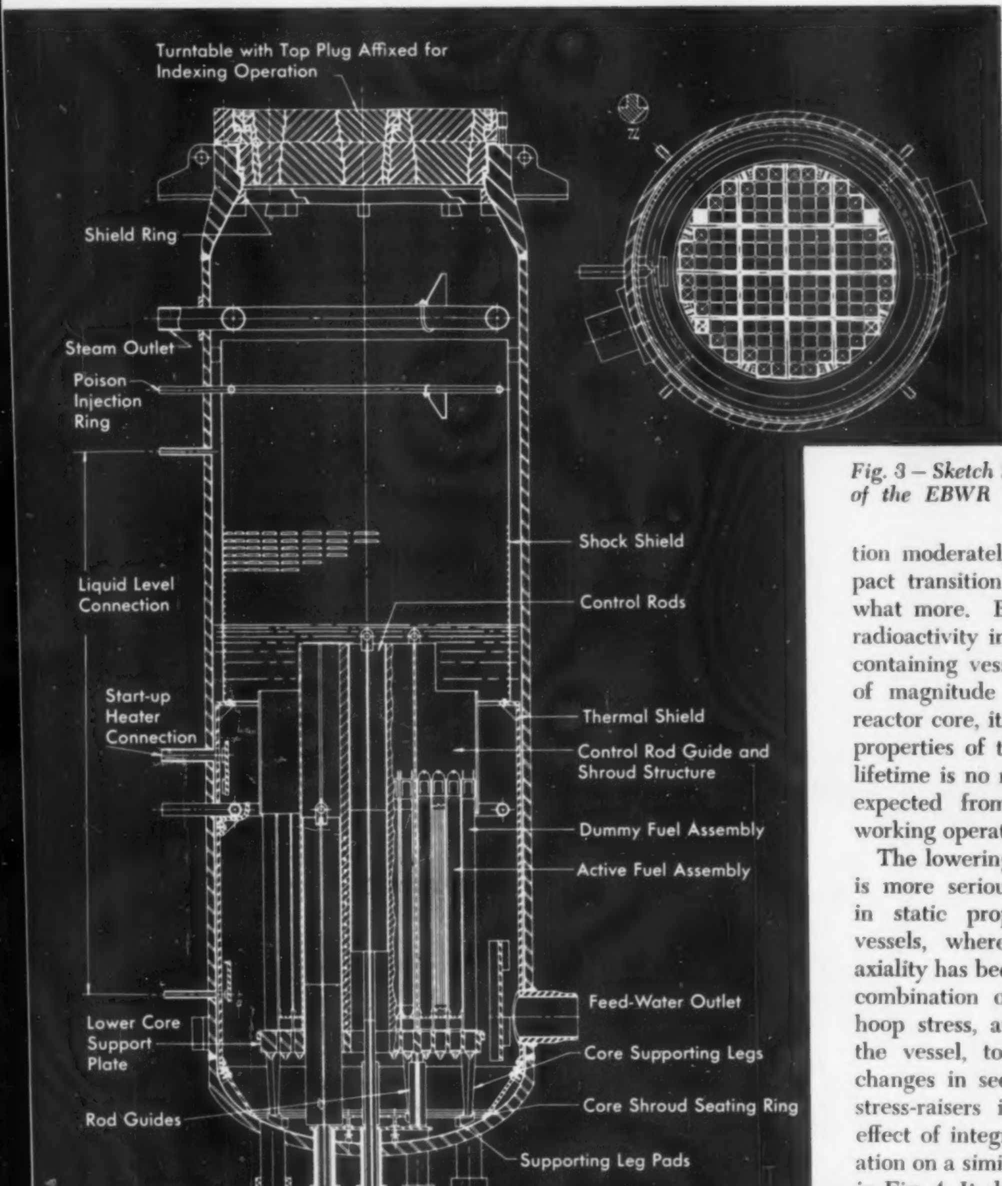


Fig. 3 – Sketch Showing Details of the EBWR Pressure Vessel

tion moderately, and raise its impact transition temperature somewhat more. Because the level of radioactivity in the vicinity of the containing vessel is several orders of magnitude below that in the reactor core, its effect on the static properties of the steel after a full lifetime is no more than would be expected from a moderate cold working operation.

The lowering of impact strength is more serious than any change in static properties in pressure vessels, where a degree of triaxiality has been introduced by the combination of internal pressure, hoop stress, and axial stresses on the vessel, together with abrupt changes in section and accidental stress-raisers in the welds. The effect of integrated neutron irradiation on a similar steel is illustrated in Fig. 4. It should be pointed out that the abscissa scale in this figure is relative only, being a function of specimen size and stress system as well as of properties of the metal, and as such is not useful in establishing safe operating temperatures of a large structure. However, the fact that the transition temperature is displaced upward by irradiation is indicative of an embrittling effect in the material and must be taken into account.

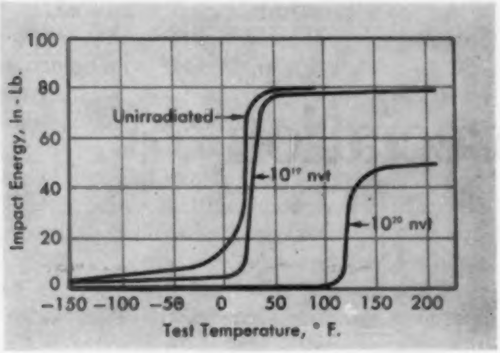


Fig. 4 – Effect of Irradiation on the Impact Properties of a Normalized A.S.T.M. A-212 Grade B Steel. Nvt is unit of neutron irradiation

For these reasons, the design must attempt to *(a)* reduce the radiation level at the vessel by interposition of barriers, if possible, and *(b)* eliminate abrupt changes of section, insofar as possible. Control is needed against stress-raisers, such as gross inclusions in the steel. Precautions in welding techniques were necessary to an even greater extent than in conventional boilers for steam power plants.

The presence of gamma radiation, apart from neutron bombardment, contributes materially to heating of intermediate layers of the pressure vessel steel, because the region of maximum absorption of these rays lies somewhat below the incident surface. The resulting temperature gradient in the wall of the pressure vessel gives rise to internal thermal stresses in the shell during operation, which was a complication not encountered in conventional boiler design.

High Absorptive Components

The thermal shield and the control rods were made of boron stainless steel, their function being to soak up excess neutrons and convert their energy to heat. The thermal shield protects the pressure vessel against too much radiation. The control rods, by progressive insertion into the reactor core, limit the chain reaction and regulate the power level of the reactor.

Boron incorporated in these structures is the absorptive agent, being about 1% (by weight) in the thermal shield and 2% in the control rods.

Because of high absorption, radiation damage by neutrons is again the villain in these materials. Boron has the evil nature of changing to lithium plus helium under irradiation. In ten years at full power, it has been calculated that the control rods of EBWR will evolve about 30 times their own volume in helium gas, which has to go somewhere.

Supports and Other Structural Materials

In the cooling system, stainless steel is used on those parts which come in contact with steam or water, because of the tenacious protective oxide film which forms and provides a shield against further attack.

Common structural materials, unless they contain highly absorptive chemical elements such as boron, cadmium, or some of the rare earths, are not serious targets for irradiation damage, especially in the absence of impact, triaxial, or cyclic stresses. Problems arising with these metals are primarily those of design, rather than of material. This is not to minimize their importance, but only to classify them as being of secondary interest to metallurgists.

The Metallurgical Role

Metallurgists, of course, participate directly in the production of fuel elements. Another function of the metallurgist in the design and construction of reactors is to build up a fund of knowledge about promising new metals and alloys – their mechanical and thermal properties, their behavior under irradiation and under corrosion in unusual mediums. This fund of new data should not only be made available but also actively brought to the attention of the reactor engineers on its own merit.

Those who are charged with the design of reactors must consider the needs of physics, heat transfer, materials, economics and a welter of other available information. So their reluctance to specify a promising new superalloy is probably made on the basis of something far removed from the arts of metallurgy. Two reactors later it may be just what the doctor ordered. In addition, some better acquaintance with it in the interim will give increased confidence to the people who must share in the risk of its employment.

Meanwhile, the metallurgists try to anticipate requirements of a few years ahead in the assurance that a fair number of jackpots will more than pay their way.

EDITOR'S NOTE: The complete technical story of Argonne Laboratory's EBWR is now available in book form as one of the Nuclear Technology Series, sponsored by the U.S. Atomic Energy Commission. The paper-bound volume, "Experimental Boiling Water Reactor," can be purchased from the Superintendent of Documents, U.S. Government Printing office, Washington 25, D.C., for $2.25.

Biographical Appreciation . . .

J. Robert Townsend

Director of Materials
and Standards Engineering
Sandia Corp.

J. Robert Townsend's career is another of those reassuring bits of proof that this is a land of opportunity. The son of a Baltimore church-muralist and choir director, young Bob's early ambition was to become a doctor. But when his father's health failed, he was forced to leave school and go to work.

Recognizing that medicine was not a very promising field for a man seeking to educate himself while working, Townsend fixed his hopes on engineering. His only preparation, aside from a natural curiosity about the nature of things, was the fundamental training in general science which had made up his premedical studies at Baltimore City College. So armed, Bob Townsend in 1920 began his long and distinguished career with the Bell Telephone System.

His first job was in the development laboratory where he was assigned the task of evaluating the Bower-Barff finish for steel desk telephones. Thus at the very outset he tackled a metallurgical problem, and it was on this early assignment that he began to formulate the principles upon which he has based his entire career. Townsend puts it this way: "In order to evaluate a material or a process, you must first bring it under quantitative control and measurement. If you can measure, you can evaluate change." This was 37 years ago. Today, as director of materials and standards engineering at Sandia Corp., in Albuquerque, N.M., Townsend is applying this same principle to the study of the effects of radiation on materials.

During his early years with the Bell System's old laboratories on West St., New York City, Townsend supplemented his experience with courses in mechanical engineering at Brooklyn Polytechnic Institute. Although he never received a college degree himself, Townsend is a strong supporter of formal education. Last year 17% of the scientists and engineers in his organization took graduate courses at the University of New Mexico. Technicians in his group find it easy to get assigned to night jobs if they wish to attend university classes during the day.

Townsend attributes the fact that he has been able to succeed in a highly technical field despite limited formal education to two things. First, he points out, the Bell Laboratories is one of the world's greatest educational institutions. Second, he adds, truly competent professional people are always willing to share their knowledge and insights with others.

But his colleagues are likely to point to other reasons for his success. For example Robert Poole, vice-president of development at Sandia, and for 30 years an associate of Townsend's, has this to say: "Over and above a high level of competence, Bob Townsend has three characteristics which have made him a leader: dedication to a purpose, intolerance of mediocrity, and the ability to get top people to work together."

The objective to which he has been dedicated throughout his career is that of seeking out the unique properties in materials which particularly suit them for specific applications. In this field he was one of the pioneers in bringing order to the testing of nonferrous metals. This activity led to his being made chairman of the group which resolved the metals, coatings, insulation and processes to be used on the Havana-Key West telephone cable, and later broadly applied to the transatlantic telephone cable.

Because of his interest in quantitative measurement and process control, Townsend early acquired an interest in the development and application of standards. He organized and developed the first materials and environmental laboratory at the Bell Laboratories and did much to establish the concept of materials engineering as it is practiced today. Both through his work in the Bell System and as a consultant to the Office of Defense Mobilization, Townsend has worked to establish the broad principles of substitution and conservation of materials. These principles have led to the present-day concept that conservation is best achieved by utilizing the unique properties of every material in optimum applications.

Townsend made direct contributions to our national defense in both world wars. During World War I, he served as a civilian consultant at the Aberdeen Proving Grounds. Since the beginning of World War II, he has been consultant to or member of a long list of committees and study groups in the field of materials. A complete listing of these activities would be rather formidable, but a few will be noted. He was, for example, a member of the Technical Industrial Intelligence Committee of the Foreign Economic Administration which investigated German technology and processes in 1945. From 1949 to 1951 he was chairman of the Panel on Ordnance Materials of the Research and Development Board. At the present time he is consultant to the Assistant Secretary of Defense for Research and Development and to the Office of Defense Mobilization; a member of the Technical Advisory Panel on Materials and of the

Advisory Committee on Materials to the American Standards Association; and chairman of the Panel on Ordnance Materials. He is also chairman of the Materials Advisory Board of the National Academy of Sciences, a group of scientists engaged in materials problems under contract with the Department of Defense and the Armed Forces.

The two professional organizations in which Townsend has been most active are the American Standards Association and the American Society for Testing Materials. In the former, he has, during the past quarter century, worked on six standards committees and nine administrative committees and has participated in six standardization projects. Recently he was nominated by his associates for the office of vice-president and for award of the Standards Medal.

In the A.S.T.M. he has been no less active. He served as a member of the executive committee from 1938 to 1949, and was in turn vice-president and president. He was awarded the Dudley Medal in 1930 for his work on standards for nonferrous metals.

No attempt will be made even to summarize the long bibliography of articles and papers which Mr. Townsend has contributed over the years. Suffice it to say that it began in 1927 with a study of telephone cable sheath alloys and ranges widely across the field of metals, standards, and testing. One of his most recent endeavors was a study of the national nickel situation prepared for the Office of Defense Mobilization. He recommended that the base of production be broadened and that nickel be thus made available for present and new uses rather than creating scarcity by enforced stockpiling.

In 1952, Townsend assumed his present post with the Sandia Corp., a Western Electric subsidiary engaged in ordnance work for the

Book Review...

An Introduction to Physical and Process Metallurgy

*Reviewed by J. GORDON PARR**

TEXTBOOK OF METALLURGY, by A. R. Bailey, MacMillan & Co., Ltd., Rev. Ed., London, 1956. 560 p. 30s. net.

IN WHAT we are led to believe were the good old days of 50 or 60 years ago, a man might compile a textbook of metallurgy and, in the compass of a few hundred pages, write pretty well all that his readers expected on the subject. Or, even if he failed to do this, his readers were usually broad-minded enough to forgive him his omissions. But today, in an age when thousands of pages of script are written about such trivialities as right-handed screw dislocations in body-centered tetragonal structures, each of us is usually aware of the depth of one or two very narrow topics, and we are therefore much less tolerant of general textbooks with a wider subject range. When we *do* read a general text, we are ready to leap upon the author for leaving out material that pertains to our own forte, but we are rarely ready to admit that most of the book contains material with which we are not very conversant.

Mr. Bailey's book is already a familiar introduction to metallurgy. It describes itself as a "modern and thorough introduction to physical and process metallurgy for students of metallurgy at universities and technical colleges". As an introduction to metallurgy it is excellent in its content and clear in its presentation. While I hope that the students to whom Mr. Bailey directs his book read it, I think that it is also the sort of text from which almost any of us might benefit. It is, for example, a book that a steelmaker should keep on his shelf so that when

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Atomic Energy Commission. As director of materials and standards engineering for this 6800-man atom-age laboratory, Townsend has had a unique opportunity to combine his interests in a comprehensive program.

The very structure of the organization he has assembled at Sandia reflects his philosophy of materials engineering. One of his three departments is devoted entirely to materials engineering. The second is responsible for developing and maintaining primary standards for the entire A.E.C. complex. The third is engaged in large-scale testing of materials and components and is equipped with centrifuges, shake tables, drop tables, drop towers, and even a 3000-ft. sled track. Thus Townsend has achieved the millennium – he can analyze, measure, and test to his heart's content!

Enough has been said to give some notion of J. R. Townsend as a metallurgist and a man of science. But Bob Townsend has always found time to lead a full life away from the laboratory.

The comfortable home in which he lives with his wife and 21-year-old son Peter Grey Townsend is full of signs of this other side of his life. The walls are decorated with Townsend originals. (Mrs. Townsend explains that these are a result of the depression in the 30's. The Bell Laboratories at this time went on a four-day week, and her husband took advantage of the enforced leisure to attend art school and has continued to paint as a hobby ever since.)

Other hobbies include camping, golfing, riding, sailing, gardening, hunting, leathercraft, and carpentry, at most of which he is unusually proficient. His approach to such activities is exactly the same as that to his professional activities – "You figure out what you want to do and how to do it – then get at it!"

W. F. Carstens

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a nephew phones to ask how the electron microscope works, or what, precisely, is meant by "peritectic", or how lead is de-silvered, the questionee has more than the bluff of his profession to work with.

I suppose a reviewer might demonstrate his cleverness by pointing out what appear to be a few small errors of fact, but these are so slight that to mention them would throw into a wrong perspective all that is good about the book. He might, too, express his disappointment that in a modern book, even at an introductory level, subjects such as high-temperature alloys and titanium metallurgy are not included. But such omissions are, I think, inherent to the pattern of Mr. Bailey's text. After an introduction to physical metallurgy (175 pages), the extraction metallurgy sections deal first with general principles and procedures (97 pages) and then with specific processes (82 pages). The book concludes with chapters on fabrication (92 pages) testing and pyrometry (50 pages), appendices of data and equilibrium diagrams, and questions. In such a framework there is no easy way of dealing with the mechanical properties, treatment and uses, of specific metals and alloys, except when examples are needed to illustrate a particular point in the text.

Mr. Bailey's difficulty is, perhaps, illustrated by the fact that a few pages on the physical metallurgy of iron and steel are inserted rather uncomfortably into the chapter on iron and steelmaking. But clearly, if Mr. Bailey had woven threads of the engineering metallurgy of many alloys into his already tight fabric – in fact, if he had inserted everything that he perhaps felt inclined to – the book would have been a most unwieldy one. It might also have become something more than an introduction. Therefore, while another author of another 560-page textbook of introductory metallurgy might have used a completely different approach with, probably, quite a lot of different material, this does not detract from the value of Mr. Bailey's book.

Since the book was written and published in England, prospective readers might anticipate the use of odd British specification numbers, and, possibly, descriptions of old English practices. They would be mistaken; the book is free from code specifications and appears to be up to date on processes that are used throughout the world. The only non-American convention is the use of the Celsius temperature scale, and to my way of thinking, this is one of the more sensible quirks of the British. It should be pointed out, too (but this shows the other side of the coin) that although the book is "Revised and Reprinted, 1956," it contains very few and very minor changes from the original 1954 edition. If you have the 1954 copy, don't get another; but if you have no copy at all and like to dig wide instead of deep, the book is a good buy.

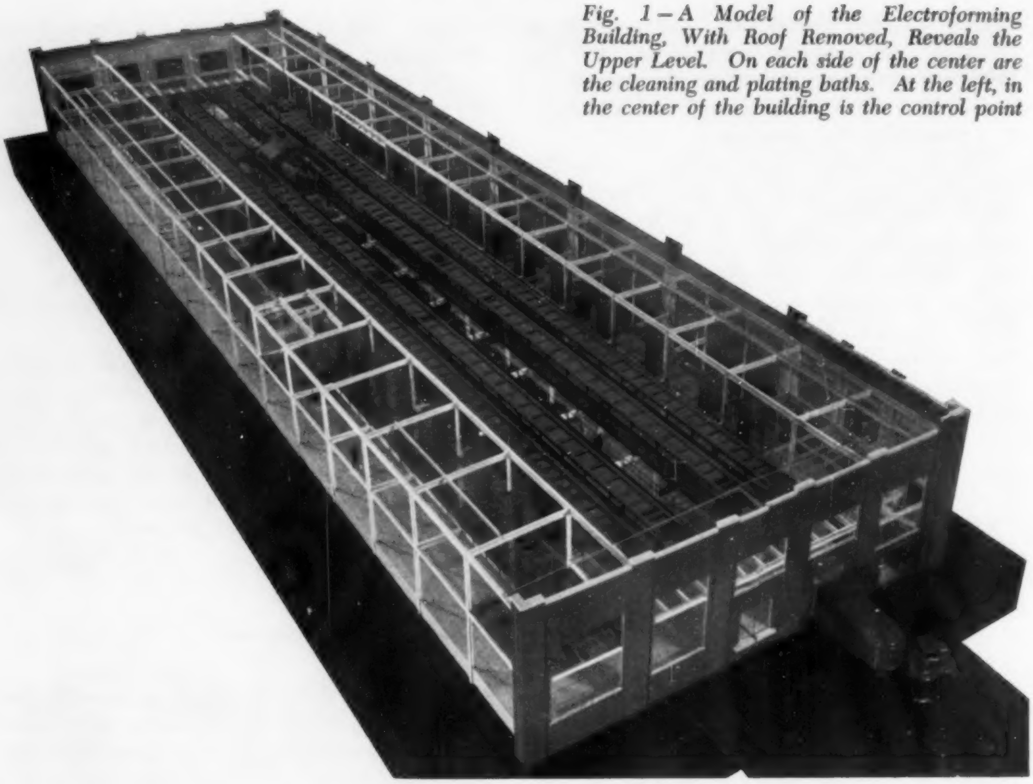


Fig. 1 — A Model of the Electroforming Building, With Roof Removed, Reveals the Upper Level. On each side of the center are the cleaning and plating baths. At the left, in the center of the building is the control point

Electroforming of Telephone Drop Wire Conductor

*By ROBERT J. BACHMAN**

TELEPHONE DROP WIRE, the familiar aerial service connection between the telephone pole and the customer's home, consists of a pair of copper-clad steel conductors positioned in a cotton-wrapped rubber extrusion covered by a black neoprene weatherproof jacket. Nearly two billion conductor feet of this wire is required by the Bell Telephone System annually. In order to meet these needs, the Western Electric Co., the System's manufacturing and supply unit, has designed and built an electroforming plant at its Point Breeze Works in Baltimore, Md.† There two huge electroforming machines operate 24 hr. a day to make the copper-clad steel conductors. The plant layout and processes are

*Engineer, Western Electric Co., Inc., Point Breeze Works, Baltimore, Md.

†EDITOR'S NOTE: Generally the term electroforming is applied to a somewhat different process in which a metal shape is built up on a disposable matrix through electrodeposition. In the Western Electric process the functional properties of a wire are substantially changed, and the term is used to distinguish from purely decorative electroplating.

Conductance is precisely measured and thickness of metal deposition is controlled as steel wire is coated with copper, lead, and brass at the rate of 100 ft. per min. (L17, T1b, 17-7; ST, Cu)

unique in many ways. Fifty continuous wire strands are simultaneously coated. Automatic instruments and controls measure and control conductance during the plating operation.

The operation begins with a steel wire which must be coated with adherent copper. The copper serves the dual purpose of lowering the electrical resistance of the conductor and providing corrosion resistance for the underlying steel. Steel provides the conductor with the strength required for drop wire service, but high strength must be tempered with a moderate amount of elongation or ductility. Meeting these specifications, the wire will give adequate support to distributed loads such as ice and wind and also resist shock loads imparted by falling tree limbs and other debris during storms.

The core material is a single strand of improved plow steel of the type used in making wire rope. It is a hard drawn wire with approximately 0.65 to 0.75% carbon and meets tests of 250,000 to 290,000 psi. breaking strength. The steel core wire measures 0.033 in. in diameter within commercial tolerances.

Because the surface of the wire as received from the steel manufacturer is covered with some oil, dirt and wire drawing compounds, the first operation in the process must remove these contaminants. Cleaning is done by passing the wire through a heated, specially formulated alkali solution in which the wire is anodic. A vigorous evolution of gas, caused by passage of electric current in the presence of the alkaline solution, removes these unwanted compounds effectively.

The next step removes traces of rust or scale on the wire in a sulphuric acid pickling bath operated at room temperature. A light etch given to the wire in this solution assists materially in promoting a firm bonding surface on the steel for the subsequent copper application.

A critical operation in the process is the first deposition of copper over the steel core which follows the cleaning steps. At this point, an immediate introduction of the steel into the more efficient acid-type copper plating bath is not feasible because a nonadherent galvanic replacement coating of copper would cover the bare steel. To prevent this occurrence, the Western

Fig. 2 – Steel Core Wire, Fanning Out From the Reels. In the distance a worker is butt welding the end of one reel to the beginning of another

Electric process calls for the steel to be given its initial coating of copper in a combination of two different copper cyanide baths, which produce a total deposit slightly more than 0.0001 in. thick. A fine grain structure in the copper coating, a result of precise adjustments of the deposition current densities and chemical compositions, tends to produce a fine crystalline structure in subsequent applications of copper over this preliminary coating.

Clad with a thin, fine-grained coat of copper, the wire enters an acid type plating bath where the copper can be deposited at a rate several times as fast as occurs in the alkaline copper cyanide bath. The acid solution is a combination of fluoboric acid and copper fluoborate. Though copper fluoborate is highly corrossive, its use is more than justified by the high current densities obtainable – 2000 amp. per sq.ft. of wire surface being entirely feasible.

When wire leaves the copper fluoborate solution, the copper thickness has been increased to approximately 0.0025 in. Although the 0.0025-in. thickness of copper is perfectly uniform around the steel, it still possesses the columnar grain structure characteristic of electrodeposits. In order to obtain a fine random grain structure, the wire runs through an annealer which is heated by a flow of alternating current in the wire. As the wire leaves the annealer, it is quenched in a bath of cold water. Three important changes occur during the annealing operation:

1. The copper becomes fully annealed, giving it a fine random grain structure that provides additional corrosion protection to the steel.

2. The electrical conductivity of the deposited copper is increased.

3. By virtue of subcritical heating, the steel is strain relieved. This increases the elongation properties of the steel without appreciably sacrificing its breaking strength.

Although the annealer has a steam atmosphere so as to reduce the tendency of copper on the wire to oxidize, some unavoidable oxide formation must be removed by a passage through a bath of fluosilicic acid, the next step of the process.

After copper plating is completed, the conductor receives a thin coating of lead (from a lead fluosilicate solution) which in turn is covered by a thin layer of brass, both electrolytically deposited. A chemical reaction between the sulphur in the rubber and the copper in the

Fig. 3 – From the Supply Reels at the Left, the Wires Are Guided at the Right to the Upper Level for Subsequent Plating

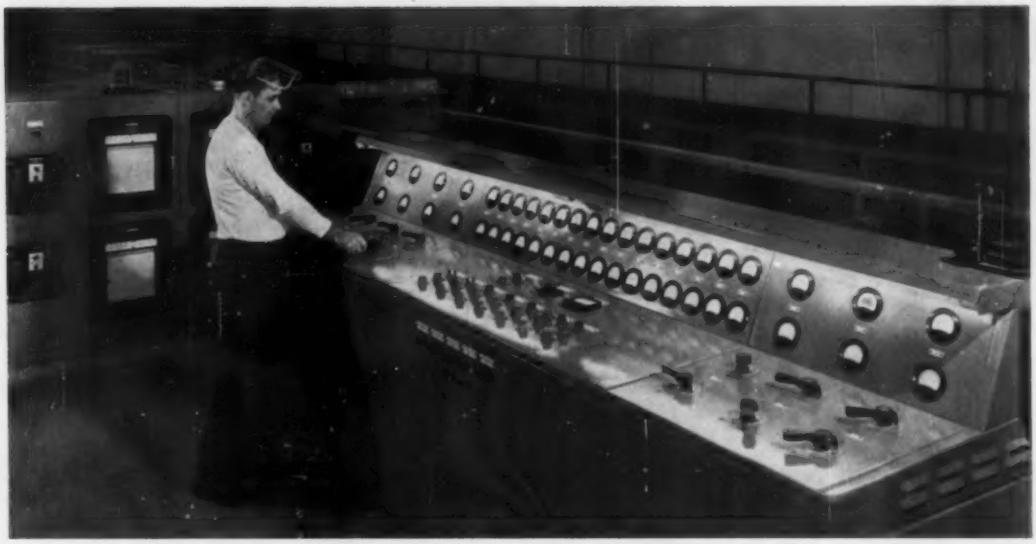
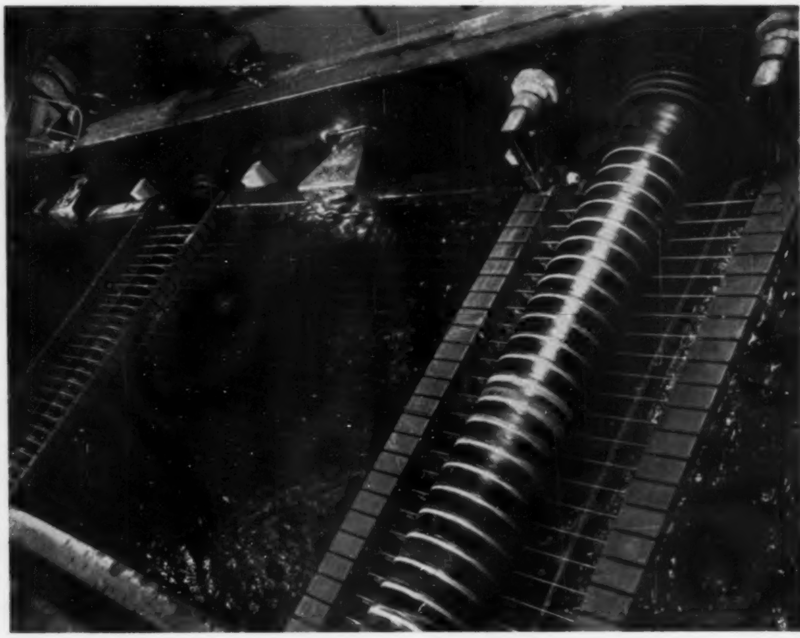


Fig. 4 – Central Control Point. All meters, controls and recording instruments are together for easy reference

brass provides a high degree of adhesion between the conductor and the rubber extruded around the wire in the subsequent insulating process. Insulation is applied in a separate building. The thin continuous barrier of lead interposed between the brass and the thick coat of copper effectively prevents the chemical action initiated by the sulphur from penetrating below the brass into the copper. Lead and brass deposits are each only a few millionths of an inch thick. Brass is applied in a copper-zinc cyanide bath in which temperature, current density, pH, and chemical concentrations are controlled to very close tolerances.

Fig. 5 – A View From One End of the Building at the Upper Level. The row of cells directly in view forms one half of the total cells for each machine

Fig. 6 — A Typical Cleaning or Plating Cell, With Narrow Sections on Each Side of the Cell Receiving the Overflow of Liquid From the Slotted Weirs



The plating machine is divided between two building levels. Cleaning and electroplating operations are performed exclusively on the upper level in the order described above. Operations in the lower level of the building include steel wire payoff and windup; material handling; solution mixing, storage, filtration, pumping, and heating.

Steel wire is supplied to the machine from the manufacturer's reels. Provision for an automatic transfer from the last wrap on any emptying reel to a new full reel makes the wire feed continuous. Wire is fed "over-end" from stationary reels lying flat on one end. Provision is made for the accessibility of the inner ends of wire coils so they can be joined at will to the outer ends of subsequent reels, thereby obviating the need to stop operations to produce a continuous wire feed. A butt weld which joins the last wrap on the emptying reel to the first wrap on the standby full reel is not as strong as the wire itself and is removed at the wind-up operation. With this arrangement, plant operation is carried on a seven-day basis with no scheduled shutdowns.

Twenty-five wires are simultaneously processed side by side in one machine. Wires are kept separated at fixed distances, are propelled and electrically energized by passage over and under 104 grooved metal rollers. Uniform tensions and a closely regulated speed of 100 ft. per min. are obtained from an electronically controlled drive system.

Direct current power, essential to the electrolytic operations, is provided by copper oxide water-cooled rectifiers. The direct current output from the rectifiers is automatically regulated to the proper value through equipment which measures the electrical resistance of the copper-steel conductor as it leaves the last plating bath. An exceptionally uniform product results from this close control.

The cleaning, depositing and annealing sections of the machine total approximately 600 ft. in length and each of the 25 channels contains a wire span of about 850 ft. from payoff to windup. On the upper or processing level each machine consists of sets of tanks arranged in the form of a rectangular "C", the long axis of which is about 300 ft. Wires to be plated rise from the lower to the upper level at the opening of the C, travel through the sets of plating tanks, and descend to the lower level again at the opening of the C. Pay-off and windup stations are in line on the lower level beneath the machine for about three-quarters of its length. The building itself is 340 ft. long.

Carefully planned for substantially automatic production, the plant is fully manned for round-the-clock operation of both machines by only six men per shift with the assistance of a material handler on one 8-hr. shift.

Present Utilization of Titanium

STAFF REPORT

Still too costly for common use, titanium and its alloys are finding many military and civilian applications where high material costs can be justified by the advantages obtained. Greater uniformity of properties, variety of alloys available, lower cost and added user experience point to a steady increase in titanium's future acceptance. (T24, T29, T2, 17-7; Ti)

TITANIUM has been described in the recent past as the metal with a promising future. How is that promise actually working out? We learned the answer to this question at the Titanium Conference held concurrently with the Western Metal Congress in Los Angeles in March 1957.

In general, titanium is living up to its promise; in fact it can be said that some of the implied pledges are redeemed. There are three fields where titanium is in use now – military aircraft, army ordnance equipment and the process industries. To be sure there have been some ill-fated starts; experience again serves as the best teacher.

Titanium's acceptance isn't new as a story of the use of metals. During the last century, aluminum has grown from an interesting laboratory curiosity to an indispensable metal. Magnesium has followed this same course in the lifetime of many of us. Now comes titanium to help satisfy new metal demands.

Each of these metals had something different to offer, although aluminum, magnesium, and now titanium all offer low weight per volume. The first automobiles had no aluminum; today's use a significant quantity. Magnesium, when first tried by the car-makers in the 1920's, stumbled, and not because of price alone. Will titanium ever be used in automobiles? Probably not until it has more generally matured in aircraft use.

Several recent meetings under auspices have highlighted the hot strength requirements of metals for fast aircraft now being built and for the ever-increasing speeds to be achieved by aircraft in the future. But superior strength-weight ratios at temperatures above those possible with aluminum and magnesium are titanium's contribution to high-speed aircraft. Its corrosion resistance alone brings it into the chemical and process industries.

A recent report from an investment advisory service pointed out the properties of titanium noted above and indicated by its very appearance the widespread general interest in this misnamed "Wonder Metal". Early in World War II magnesium production was counted in pounds, thousands or millions to be sure. Even now titanium production after less than 10 years from its commercial introduction is quoted in this report in thousands of tons.

Production Increases

Consider also the actual 1956 production of 15,000 tons of titanium sponge for 5000 tons of mill products, and 1957 output of 28,000 tons to make 15,000 tons of mill products. Titanium in a single decade has equaled, proportionately, the growth of other metals which took 50 years.

In giving the present status of titanium (at the Titanium Conference) the problems yet to be solved were reported as well as the forms in which it might be used.

Well, where is it going and why is not more of it used?

Titanium's major use is for skin of high-speed aircraft, for support members and for engine parts, especially those that operate above room temperature at medium loads and must likewise be corrosion resistant. It is used for chemical apparatus in severely corrosive environments. In these uses titanium is varied in its

composition from the pure metal (for chemical plants) to alloys of 90 to 95%. This alloy picture is, of course, a changing one. The table below lists some of the currently used alloys.

Type	Specification	Composition
Ti-150 A	PWA 676	3% Cr, 1.5% Fe
Ti-140 A	AMS 4923	2 Cr, 2 Fe, 2 Mo
6Al-4V	PWA 682	6 Al, 4 V
C 130-AM	AMS 4925	4 Al, 4 Mn
A 110-AT	PWA 684	5 Al, 2.5 Sn

Aside from these familiar alloys the older 8% Mn alloy has tensile properties of the order of 110,000 psi. and the newer 6% Al, 4% V upwards of 170,000 psi. at room temperatures. Increasing molybdenum considerably in a high-aluminum alloy (Ti, 7% Al, 3% Mo) gives an alloy with highest creep resistance and rupture strength at 1000° F., and a "Schapiro Index" (yield strength divided by unit weight) of 525,000 at 1000° F.

Now we are getting somewhere! It's comparable to the stainless steels when both are heat treated.

Titanium's use in an engine mount fitting (generally cubic in shape, 6 in. maximum dimension with ⅛-in. walls) was illustrated. However there are enormous material losses along the way from the first metallic sponge to ingots and from billets to forgings and finally to heat treated finished parts. These compound the price paid for an already costly metal.

Yet titanium bulkhead assemblies are made of stretch-formed and joggled angles and curved flanges. Tail cones of interceptor airplanes are made with titanium skins. Weldments of titanium are used in spot weld designs for engine shrouds. Fusion welding can be done in inert gas atmospheres to produce seam welds.

Predictions of the rate of increasing use of titanium haven't always been met. Five years ago it was predicted that 35,000 tons would be required in airframes (considering the present weight of airframes being produced). With benefit of hindsight we now find only about 1500 tons actually used. But the prophets still expect the ratio ultimately will be achieved.

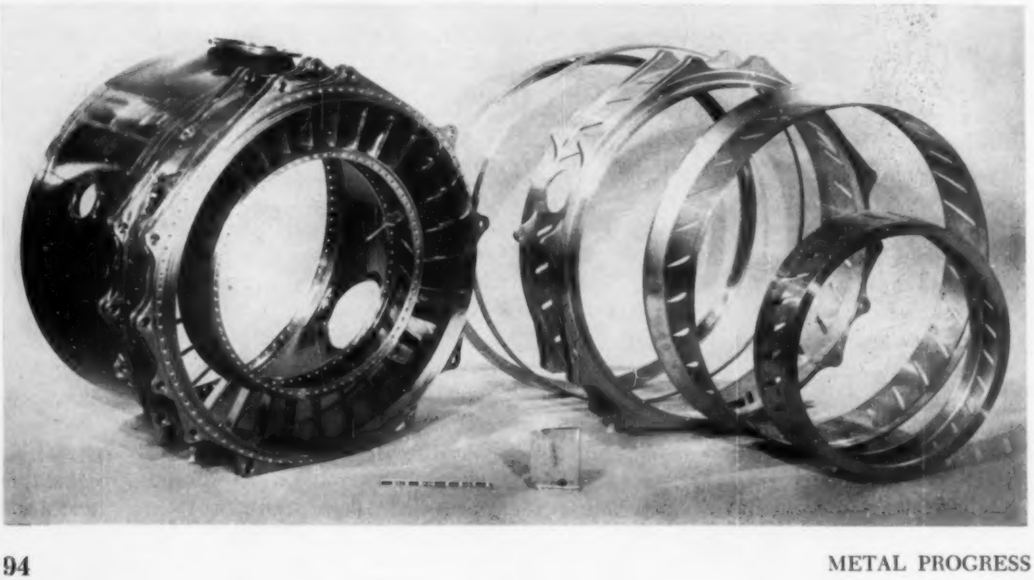
High Strengths Demanded

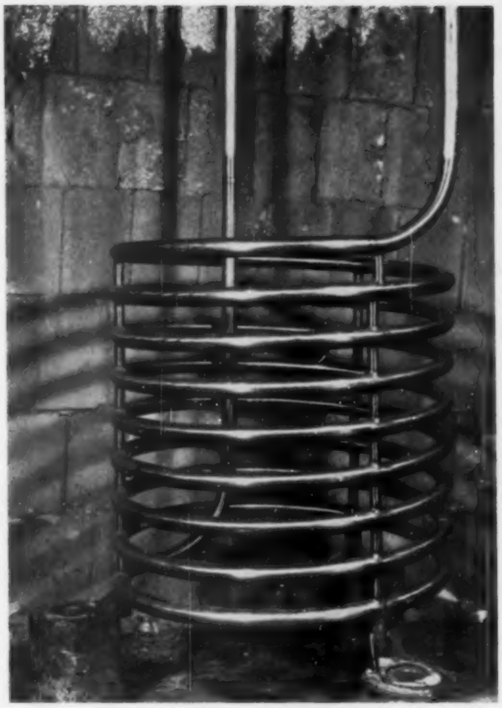
To do this the users want 180,000-psi. titanium alloys and want to get it all the time. They want 140,000 psi. at 650° F. One aircraft manufacturer would set a goal of 200,000 psi. at room temperature for forgings.

Aircraft engineers want thinner sheets that are wider, longer and to closer tolerances, and they showed just how airframes could be built for even better performance from such material. They also showed why, to achieve aircraft weight savings, they can pay for it in otherwise expensive metals. An extensive research program resulted in satisfactory titanium bolts to replace those of other high-temperature materials in aircraft applications.

The step from aircraft to missiles seems short and logical, but one is astounded by the require-

Among the Military Aircraft Applications of Titanium Alloys Are the Axial Flow Compressors of the J-57 Jet Engine (Shown Here), Engine Fittings, Bulkheads and Shrouds





Titanium Is Used In Heat Exchangers Handling Corrosive Liquids. High corrosion resistance permits use of thin-walled tubing, thus providing higher heat transfer rates

ments for materials of construction. It reminds one of the position engine designers were in at the time of World War II. Engines would last only minutes if operated at full load, full speed. Such a condition was approached in a power dive. The only reason the plane still had engines was that it could only climb so high and hence the dive took such a short time that these extreme conditions soon ran out – the planes ran out of space, so the engines didn't operate at such outputs long enough to ruin them!

Now we make missiles and they heat themselves aerodynamically but their life is measured in seconds (see William M. Canterbury, *Metal Progress* for May 1957, p. 99) so we can still have them to carry their loads and deliver their goods. But again it is a matter of rather short range.

Titanium is in real use in jet engines. While axial flow compressors were first designed in steel, titanium for blading was a "natural". Here the lower density, higher corrosion resistance and improved ratios of creep strength and fatigue strength to density were used to advantage.

Interchangeable Materials

Compressors of one engine manufacturer are of the same configuration in titanium as in steel to permit interchangeability. The manufacturing improvement has not only been in reliability with improved processing but in increased "utilization ratio" (finished weight to input weight). Compressor cases are made now of titanium, both pure metal and alloy. Inlet cases are being welded of extrusions and sheets. Forgings of substantial size are welded together to improve utilization ratios. Undoubtedly the biggest single use of titanium is in the J-57 engine, admirable from all points of view except cost which is so high that these engines are used almost exclusively in the long-range B-52 bomber, where a pound saved is worth almost anything.

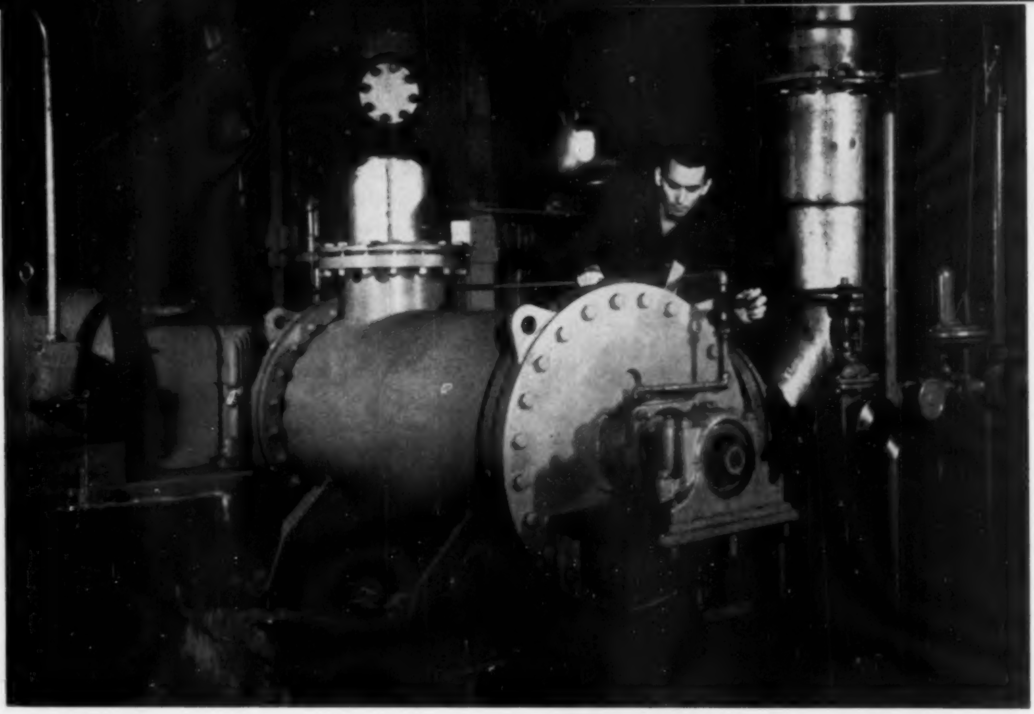
As indicated, titanium is important in today's missiles. Missiles are in reality unmanned airplanes operating in the speed range of many Mach numbers. When you consider the thermal limitations of materials in terms of the steady-state skin temperatures due to aerodynamic heating at any given altitude, say 30,000 ft., aluminum is good to about Mach 2 (400° F.); titanium to Mach 3.5 (1000° F.) and the nickel alloy Inconel "X" to Mach 4.5 (1500° F.).

By "Chem-Mill" process, weight in lower stress areas has been reduced in a typical rib section built up by welding. Titanium is also being actually used in missile parts that are brazed together – as, for example, in heat exchanger tubes and in bearing housings.

Brazed joints are used in electrical and electromechanical systems. Joints are between titanium and corrosion resistant steels, both austenitic and heat treatable ferritic types. Brazing is done inside glass or plastic containers with induction heating, so time at elevated temperature is so short that embrittlement due to diffusion of the brazing alloy into the titanium is minimized. In missiles, as in airframes and engines, large cases and load-bearing covers are being made of titanium. In missiles, electrical requirements often demand metals of high conductivity, so plating with precious metals permits its use in spite of the low electrical conductivity of titanium and its alloys.

Military Armor

The Air Force is not the only group that is weight conscious. The Army is using titanium because of its strength-weight ratio, since nowadays mobility is so important.



Titanium Is Being Used Increasingly to Line Tanks and Vessels. Chlorine dioxide is added to paper pulp for bleaching in this titanium-lined mixer

For instance, they are using titanium to replace steel armor. Weight saving amounts to 25% for the same ballistic protection. Again, by using titanium in the running gear, as much as 5% of the total weight of a tank is saved.

Man-carried equipment can be lightened, as for example in flame thrower fuel and gas tanks. When titanium is used for a mortar base plate one man can carry it where two men formerly were required.

Process Industry Uses

We heard early that titanium was used in the chemical and process industries and there it has made remarkable strides. Here the important property is corrosion resistance rather than strength-weight characteristics. For example, highly corrosive slurry is handled in the Cuban plant where nickel and cobalt are being separated from a complex iron ore.

A titanium jet after-condenser, in service for more than 33 months continuously, replaces a stainless steel unit that failed in six. Brackish water shows no measurable effect on the titanium even though the solution also contains dilute nitric and organic acids. Titanium is outlasting stainless four to one in handling a nitric acid solution with free nitrogen oxide at 400° F. and 350 psi. Here welded coils as well as agitators, thermowells and valve trim are used. Low thermal expansion coefficient of titanium enables the unit to operate without increased expansion stresses.

In a steam jet diffuser at high pressures and with dilute hydrochloric acid, titanium is outlasting other materials 18 to 1. In such examples of remarkable corrosion resistance it is easily recognized that the material's high initial cost can be justified. Longer life reduces both the cost of replacement and permits continuous operation without down-time. In some instances the use of titanium has permitted higher process temperatures or process solution strengths with resulting efficiency increases and without corrosion hazard.

In process industry applications commercially pure titanium has been most generally used. It has adequate strength, works and welds easily, and has the required corrosion resistance. Sheets, plates, wire, bars and forgings are all being used.

Welded food processing kettles were illustrated at the conference. A mixer with titanium lining for bleaching paper pulp and a heat exchanger were other specific examples shown. Titanium shells are also being used as tank and pressure vessel liners in the process industries. Rem-Cru Titanium reports its orders for civilian uses for 1957 to be six times those in 1956 – one result of very active promotion.

So here now is the answer to a "Critical Points" question put in May 1955: "At any rate, do *you* have any use for this Wonder Metal?" An emphatic "Yes".

Relieves traffic congestion. To handle the ten million cars a year which now funnel onto the 3-lane Carquinez Bridge, (right) the State of California is building this second bridge connecting the San Francisco Bay area and the Sacramento Valley. Use of nickel-containing USS "T-1" Steel in critical truss members has simplified design...reduced unnecessary weight...saved money.

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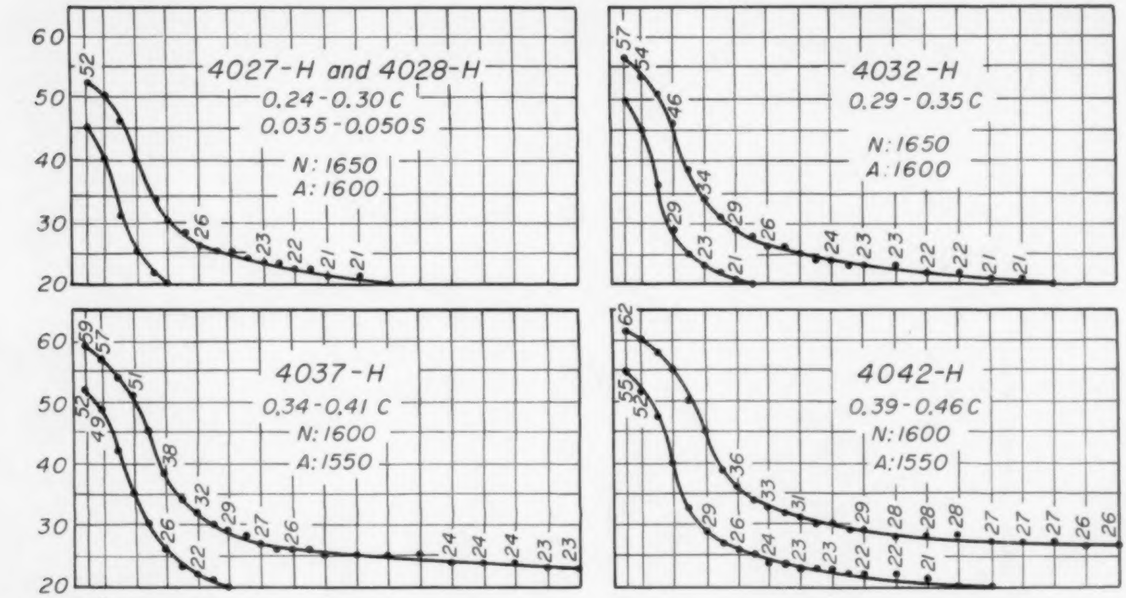
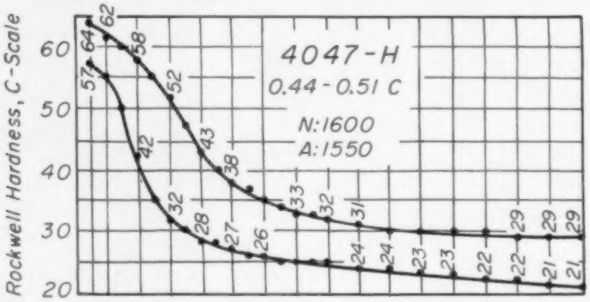


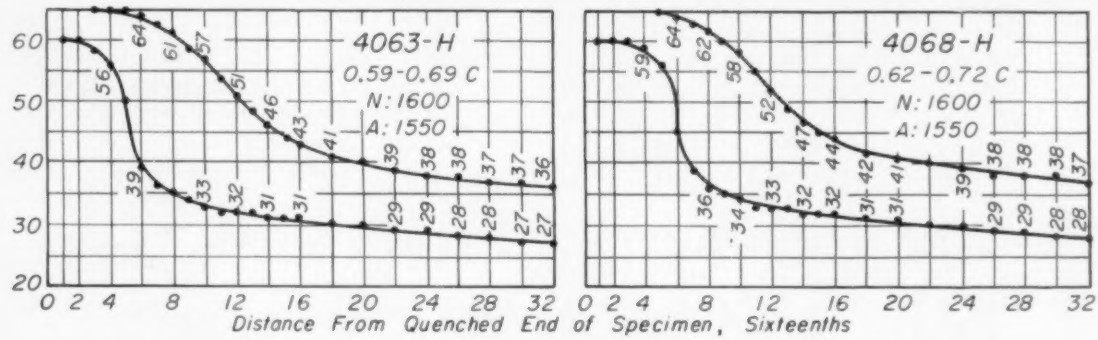


Hardenability Bands for Steels 4027-H to 4068-H

A.I.S.I. list of March 1957

4027-H to 4047-H may contain 0.60-1.00 Mn, 0.20-0.35 Si and 0.20-0.30 Mo.

4063-H and 4068-H may contain 0.65-1.10 Mn, 0.20-0.35 Si and 0.20-0.30 Mo.



N means normalizing temperature for forged or rolled material; A means austenitizing temperature (both as recommended by S.A.E.). Hardness limits are specified in Rockwell C-scale units (no fractions) and can be scaled from the plotted points where not labeled at even sixteenths.

Diameters of Rounds With Same as Quenched Hardness									Location in Round	Quench
3.8									Surface	Mild Water Quench
1.1	2.0	2.9	3.8	4.8	5.8	6.7			3/4 Radius From Center	
0.7	1.2	1.6	2.0	2.4	2.8	3.2	3.6	3.9	Center	
0.8	1.8	2.5	3.0	3.4	3.8				Surface	Mild Oil Quench
0.5	1.0	1.6	2.0	2.4	2.8	3.2	3.6	4.0	3/4 Radius From Center	
0.2	0.6	1.0	1.4	1.7	2.0	2.4	2.8	3.1	Center	

0 2 4 6 8 10 12 14 16 18 Distance From Quenched End

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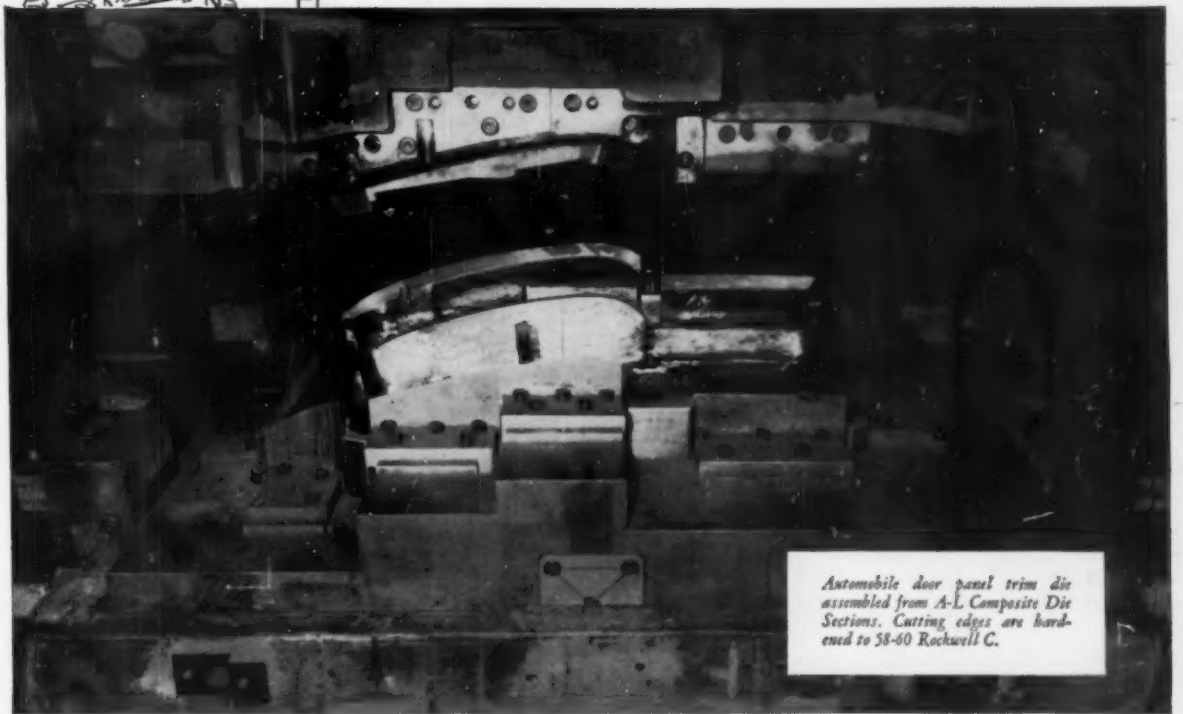

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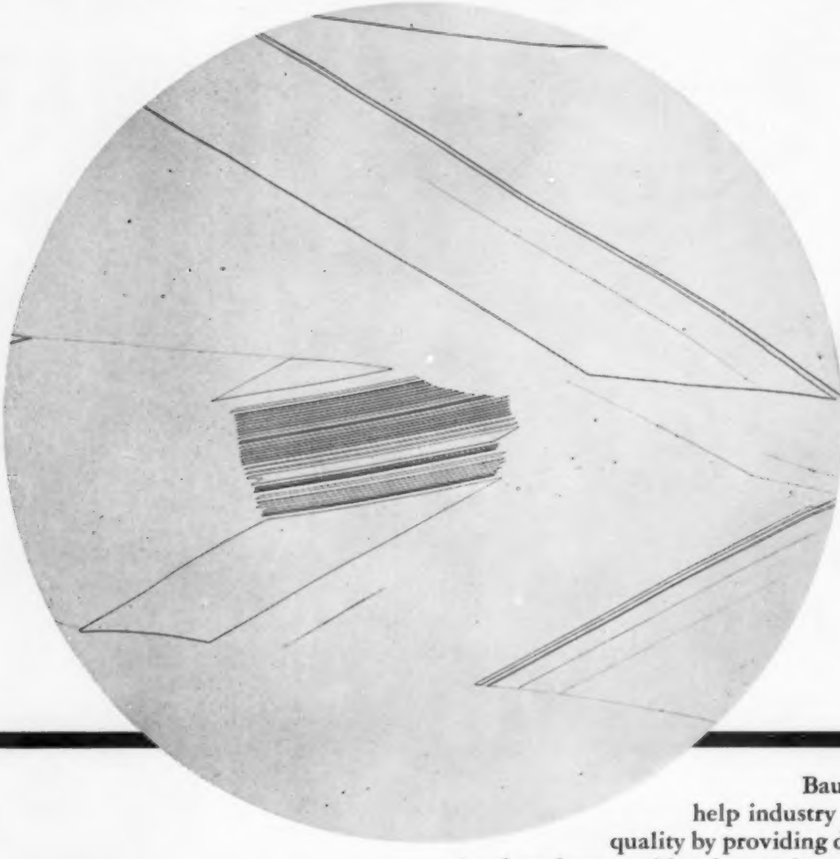

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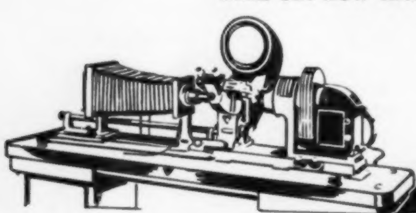

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Equipment and Procedures for Rapid Heating and Testing

STAFF REPORT

Advanced electronic equipment is needed to measure and record accurately the temperature and deformation in tests completed in seconds. Rapid heating is done by electrical resistance or in hot fluid. Results vary widely unless test conditions and metallic state are rigidly controlled. (Q general, 1-3, 2-12)

One of the most pressing and persistent needs of metals engineers today is a metal – or group of metals – capable of withstanding the complex conditions imposed by the flight of supersonic missiles. Not only are the materials subjected to constant stresses at extremely high temperatures, but the rise from low temperature to the extreme high takes place in a matter of seconds.

To find metals that will meet the rigid conditions of missile flight it has been necessary to develop a completely new set of testing techniques capable of determining high-temperature strengths. This new field of testing materials is only now reaching a state where the available knowledge of the variables involved is resulting in the development of testing equipment to provide accurate, reproducible data.

Several types of equipment were described in papers presented at the Western Metal Congress, Los Angeles, in March 1957. Salient features of the testing facilities of four different organizations were described and will be summarized here.

As Alan V. Levy, Marquardt Aircraft Co., pointed out in his paper "Performance of Materials at Elevated Temperatures", the loading of structural members in missiles and missile power plants may require that the test temperature be reached in a matter of seconds and the test completed to fracture in considerably less than a minute. Test temperatures are usually in ranges where the metallurgical structure of the alloy is unstable and the creep rates quite high. Under these conditions, the following factors must be carefully taken into account in determining the material's strength:

Short-Time Tensile Properties of 2024-T3 Aluminum at 600° F.

Testing Variables		Properties at 600° F.		
Soak Time	Testing Time	Ultimate Strength	Yield Strength	Elongation in 2 In.
90 min.	2 to 5 min.	14,000 psi.	11,000 psi.	—
30 min.	2 to 5 min.	19,000	15,000	—
2 sec.	3 sec.	27,500	—	—
10 min.	30 sec.	28,000*	—	—
100 sec.	0.08 sec.	34,000	31,700	7%
30 min.	0.08 sec.	26,500	22,000	11
100 sec.	25 min.	17,300	17,100	7
30 min.	25 min.	13,500	13,000	10
	1 to 2 min.	20,000	—	—

*Extrapolated.

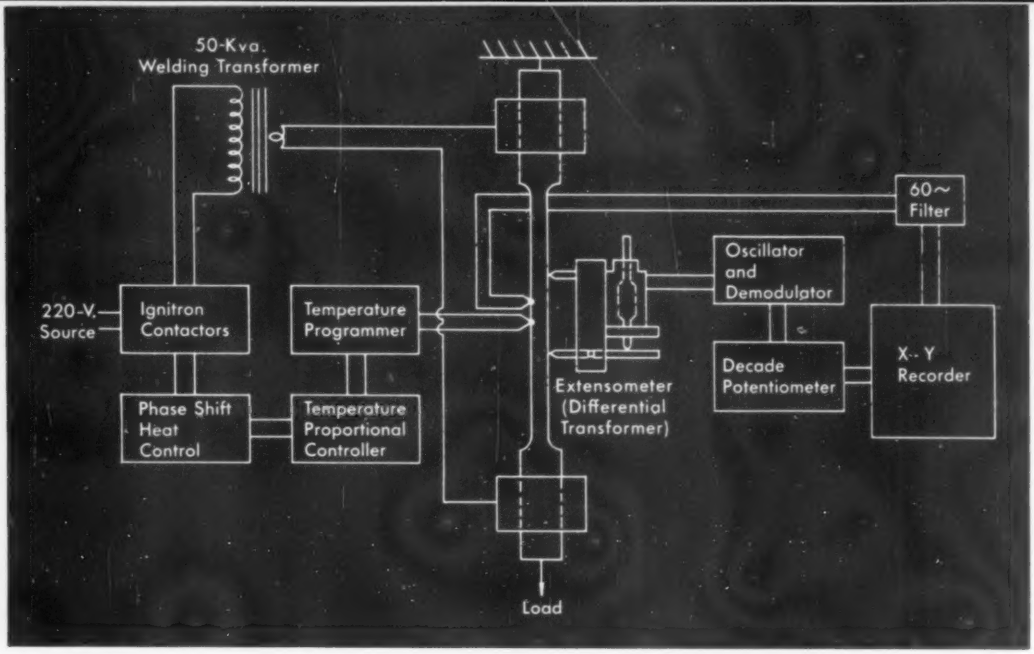


Fig. 1 – A 50-Kva. Welding Transformer Is the Heat Source in the Navy's China Lake High-Heating-Rate Testing Machine

1. Loss of strength at the elevated temperature.
2. Creep rate of the material during the test.
3. Effect of strain rate on the resultant strength level.
4. Effect of aging or other metallurgical changes during the test.

A typical example of the effect of these variables is shown in Table I. Tensile and yield strengths of 2024-T3 aluminum alloy at 600° F. as shown in the literature are assembled in this table. It can be seen that, depending upon the test conditions, tensile strengths from 13,500 to 34,000 psi. were obtained. Evidently all of the special factors cited above affected the results.

Arc Welder Heat Source

The equipment used to determine the data presented in the paper "Strength of Metals Undergoing Rapid Heating", by W. K. Smith and A. T. Robinson, U. S. Naval Ordnance Test Station, China Lake, Calif., was developed specifically for this purpose.

Two high-heating-rate testing machines are in use there. Both are capable of heating at the rate of 100° F. per sec. One machine uses a 600-amp. direct current arc welder as the source of heating current. A rheostat on the welder is set to deliver a constant current. When electrical resistance of the metal increases with temperature, the I^2R also increases. However, as the temperature of the specimen increases, heat losses due to convection and radiation also increase. Thus, the resultant heating rate is relatively constant.

A second and newer high-heating-rate testing machine uses a 50-kva. welding transformer as a source (Fig. 1). It is equipped with proportioning controls that follow the differential signal from a thermocouple and program controller, and can provide any desired temperature-time program. Use of alternating current as a heating source has certain advantages: *(a)* Voltage superimposed on the thermocouple electromotive force is damped out in the recording instrument, and *(b)* during fracture there is less damage to the specimen by arcing – thus the fracture can be studied more accurately.

In tests intended to simulate rocket service, load is applied to the specimen before heating starts. It is convenient to use a lever system when required loads are high.

Temperature of a specimen during a test is measured by iron-constantan or Chromel-Alumel thermocouples made from 30-gage wires. When alternating current is used, a second thermocouple is attached near the first. One is used for control, and the other for recording on the Y-axis of an X-Y recorder. Wires are individually spot welded near the middle of the gage length.

Strain is measured by a specially built clip-on extensometer. The stainless steel knife edges are insulated from each other to prevent short-circulating the heating current. One knife edge pivots and actuates the iron core in the differential transformer. Primary input to the differential transformer is supplied by an oscillator at 3000 cycles per sec. Output from the sec-

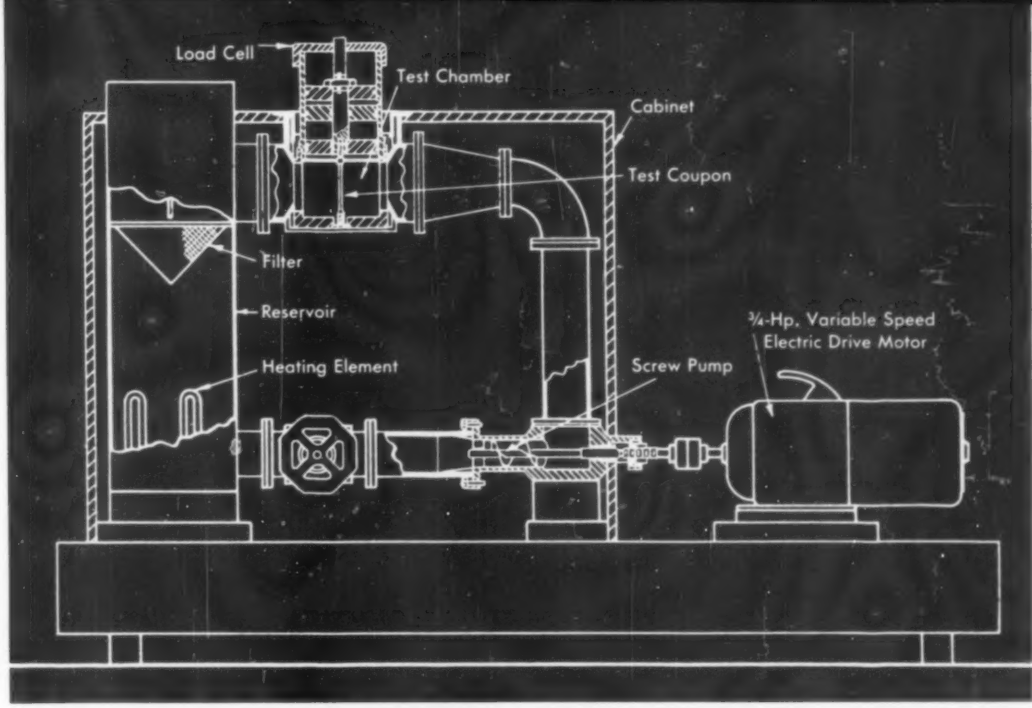


Fig. 2 – Oil Bath High-Temperature Test Unit

ondary coils is filtered to remove 60-cycle pickup from the heating circuit, rectified, and fed to the X-axis of the X-Y recorder.

Test specimens can be prepared either from bar stock or sheet. For flat specimens, a reduced section, 0.200 × 0.063 in. and about 5 in. long, has been found acceptable. The specimen should be free of notches or undercuts which might cause hot spots due to local increases in electrical resistance. Heat is unavoidably taken from specimens by the grips, so it is best to provide at least 1 in. between the extensometer knife edges and shoulders of the specimen.

Under these circumstances, temperature along the gage length will be uniform to within ± 10° F. at a heating rate of 100° F. per sec.

Fluid Heat Source

A close approximation of the conditions encountered in flight at moderate Mach numbers is achieved through the use of a hot, incompressible fluid in equipment used at Convair-Pomona Division of General Dynamics Corp. The unit is capable of heating test specimens at rates up to 60° F. per sec. and reaches maximums approaching 650° F. when using a low flash point oil. As reported in the paper "The Fluid Analogy to Aerodynamic Heating" by T. C. McGill, senior metallurgist, heating rates are controlled by the velocity of fluid passed through the test section. Velocities can be varied from 2 to 20 ft. per sec. by speed control of the prime mover.

McGill indicates that fluids other than oil can be used to attain temperatures in higher ranges. Among these are molten nitrite-nitrate salts to simulate sea level flight at Mach 3.0, and liquid metals such as lead and lead-bismuth or molten chlorides for temperatures between 1000 and 2000° F.

The Convair-Pomona test equipment (Fig. 2) consists of three main elements: *(a)* a hydraulically operated test fixture, *(b)* a heat transfer section for the fluid (which is heated to the desired temperature) where at the indicated time the hydraulic test fixture is inserted to heat the test specimen, and *(c)* the control section for all operations. All the various test units at Convair-Pomona are different in appearance although basically they operate on the same general principles.

Resistance Welder Heat Source

Test equipment used by Southern Research Institute in Birmingham, Ala., is capable of heating specimens as high as 2250° F., the maximum depending upon the material. Heating to test temperature requires 10 sec. This equipment is described in the paper entitled "Effect of Variations in Holding Time and Strain Rate on the Tensile Properties of Structural Metals at Elevated Temperatures", presented by J. R. Kattus. A typical machine is shown in Fig. 3.

Specimens are resistance heated through power supplied by a 10-kva. transformer.

Rough control of power for both heating and holding is afforded by ten transformer taps. Switches are provided, one for selecting the heating power and another for selecting holding power. As specimens approach the control temperature, relays automatically engage the holding tap.

Accurate and reproducible temperature measurements are obtained by flash welding 36-gage Chromel and Alumel wires to the specimens at intervals of 0.2 in. At 1200° F. temperature indications from the welded-on thermocouples averaged 14° F. lower than those of a reference couple. The temperature differential decreased linearly to zero at 400° F. In each test a control thermocouple is welded to the center of the gage length of the specimen and actuates a recorder controller.

Temperature uniformity in specimens is achieved by removing heat from the thinner center of the gage length by a slight stream of air.

In making short-time creep tests at Battelle Memorial Institute, a standard Battelle creep frame is used to load specimens. Stress is applied by dead weights on the end of a 9-to-1 ratio lever-arm system. Heating current is supplied by a 50-kva. resistance welding transformer operating from a 440-volt primary source. The transformer has eight steps of primary regulation together with both series and parallel secondary regulation. Constant temperature is provided through ignitrons which furnish additional power when needed.

The equipment provides heating rates, adjustable as desired, up to 600° F. per sec. Through the use of a second set of ignitron contactors for rapid transformer tap changes, controlled heating rates as high as 1350° F. per sec. can be obtained. The equipment has no maximum operating temperature except as restricted by maximum operating temperature of thermocouples or the melting point of the test materials.

Specimens used in tests carried out on the Battelle equipment were 17 × 2 in. in over-all dimensions with a gage section 8 in. long and ½ in. wide. The long gage length increases sensitivity and accuracy of creep measurements. Thickness of specimens ranges from about 0.025 to 0.065 in. depending upon the material.

Measurements of strain in the test specimens are made by a simple direct-current slide-wire extensometer unit. Extensometer rods are clamped outside the gage section at the relatively cool ends. This arrangement provides minimum thermal conduction to the extensometer. To minimize errors resulting from radiation of the hot specimen to the extension rods, the rods are made of Invar and surrounded by radiation shields of bright aluminum foil through which cooling air is blown.

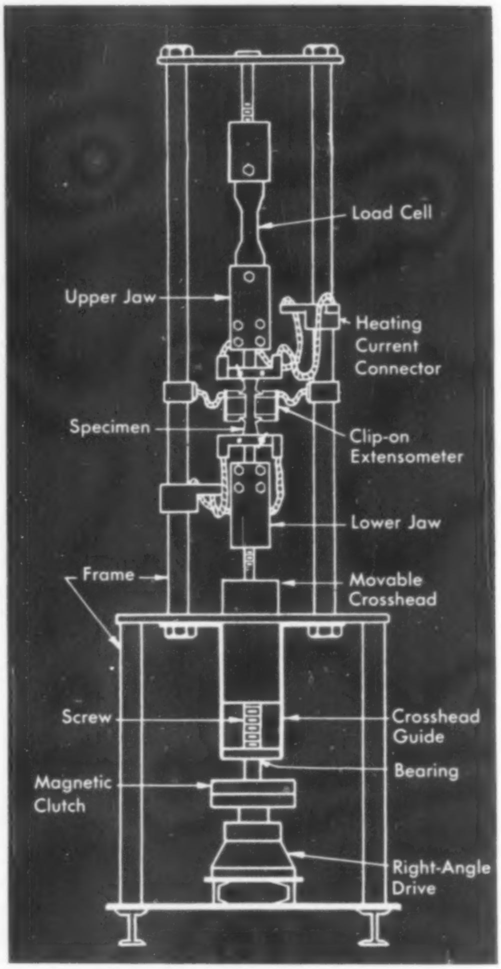


Fig. 3—In This Test Equipment at Southern Research Institute a 50-Kva. Resistance Welding Transformer Provides Heat as High as 2250° F.

A Final Precaution

One strong point made by the panel chairman was that unless all conditions of a test are made known, the data developed are of little value to another investigator. Currently there is almost no uniformity in methods or equipment for making short-time high-temperature tests, but one of the methods described by this group might well become the standard.

Recent Statistics on Metallurgical Education

*By MICHAEL B. BEVER**

While numbers of B.S. degrees in metallurgy do not now reach the postwar peak from G. I. training, the current number (545 in 1955-56) is a higher proportion of all engineering degrees. It is predicted that the figure will reach 750 in the near future and possibly 1000 within a few more years. M.S. degrees have been about 160 in each of the last three years. Ph.D. degrees show a steady increase from 42 in 1948-49 to 76 in 1955-56 (A3)

In an article entitled "The Supply of Metallurgists with Graduate Training" in *Metal Progress* for August 1955 the author reported and analyzed statistics on graduate education in metallurgy in the United States for the six academic years from 1948-49 through 1953-54. That article was based on a survey which had been conducted by an informal study group. Subsequently, the American Society for Metals Foundation for Education and Research (F.E.R.) adopted this group as its "Committee on Educational Statistics". Under this sponsorship, the Committee enlarged the scope of its interests and, in particular, included undergraduate education in metallurgy. Also the annual surveys have been placed on a continuing basis.

The members of the informal study group and of the first F.E.R. Committee on Educational Statistics were Alfred Bornemann (Stevens Institute of Technology), Morris Cohen (Massachusetts Institute of Technology), John P. Nielsen (New York University), W. O. Philbrook (Carnegie Institute of Technology), with the author (Massachusetts Institute of Technology) as chairman. This article presents the results of several recent surveys conducted by the Committee, and includes the last one which was completed in 1957 and concerns the 1955-56 academic year.

*Professor of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass. Contributions of ideas by members of the Committee on Educational Statistics are acknowledged gratefully, but the author alone is responsible for the statements made. The computations required for the analysis of the data were carried out by Marion G. Bever.

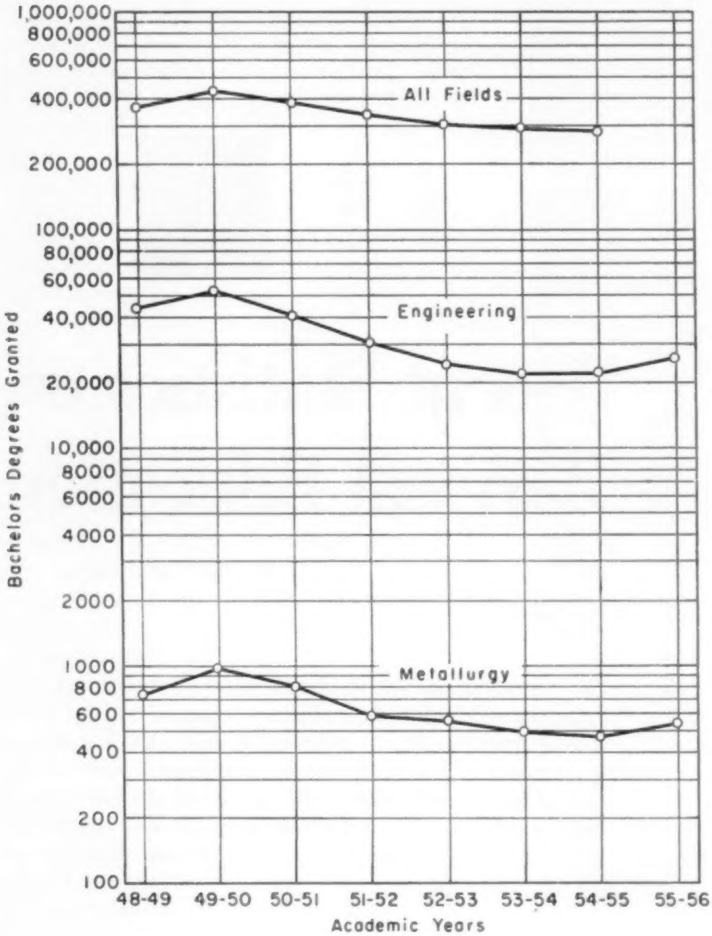


*Fig. 1 – Number of Bachelors' Degrees Granted in All U.S. Institutions Year by Year Since 1948-1949**

Method of Surveys – The surveys were conducted by annual questionnaires sent to over 60 institutions in the United States. Most of these grant degrees in metallurgy; a few have metallurgical options in other departments. In each year only three or four with small enrollment failed to answer and the numbers of degrees granted by them were taken from government publications. Information was obtained from the same source on degrees granted by two institutions which have only recently started programs in metallurgy and to which no questionnaires had been sent. Consequently the national totals of degrees granted may be assumed to be nearly complete. Although some other questions were not answered in all returns, the samples were always adequate.

The questionnaires on scholarship aid were sent to 56 institutions in this country believed to offer undergraduate curricula in metallurgy and to six in Canada; 33 of the American and all Canadian departments answered. This response represented over 60% of all departments and nearly 80% of the total enrollment. This coverage was satisfactory since the survey of scholarship aid was undertaken only to provide a representative picture.

*Sources of Data: (*a*) All Fields – "Earned Degrees Conferred by Higher Educational Institutions 1948-49" (and subsequent years), Office of Education, Federal Security Agency. (1952 and after: U.S. Department of Health, Education and Welfare.)

(*b*) Engineering – "Engineering Enrollments and Degrees, 1949" (and subsequent years), Office of Education, Federal Security Agency. (1952 and after: U.S. Department of Health, Education and Welfare.)

(*c*) Metallurgy – Same as (*b*) through 1953-54; F.E.R. Committee questionnaire thereafter.

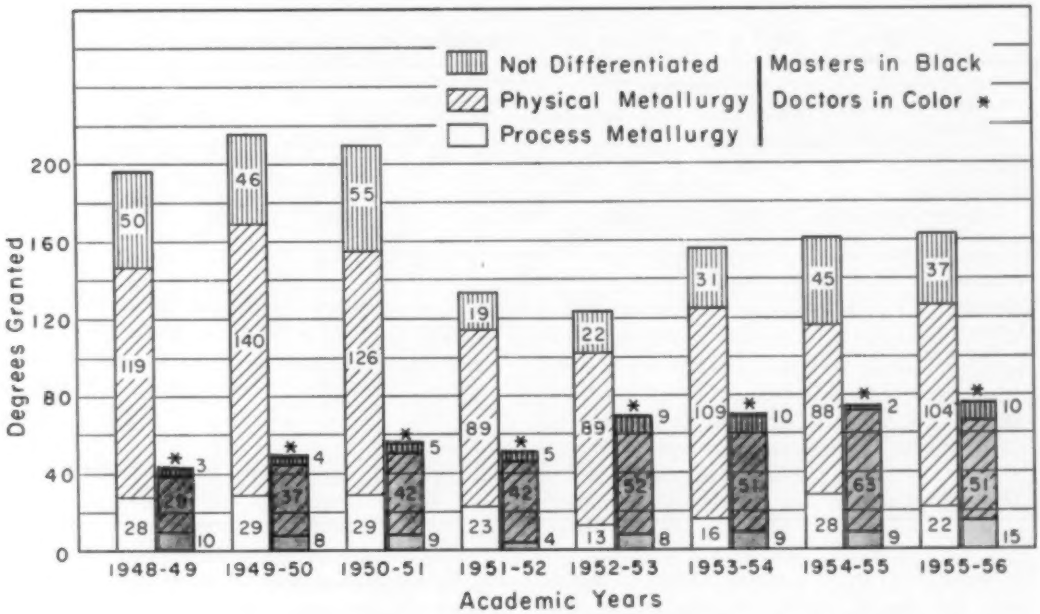


Fig. 2—Graduate Degrees in Metallurgy Granted in the U.S. During the Eight-Year Period 1948 to 1956. Black bars represent Masters' degrees; bars in color represent Doctors'

Definitions — The Committee spent serious effort on defining "metallurgy", its various subdivisions, and some other terms that were used in the questionnaires.

The latest wording of some of these definitions may be of interest.

Metallurgy for the purposes of this questionnaire comprises process metallurgy and physical metallurgy. It does not cover mining, ceramics or other related, but independent, fields.

A graduate degree in *Process Metallurgy* may be presumed to be granted to a person whose thesis was concerned with a problem in the field of process metallurgy (production or extractive metallurgy). This field is defined as the science and engineering of producing metals from raw materials. Process metallurgy includes ore dressing (mineral engineering) if the work is done in a department of metallurgy or leads to a degree in metallurgy, and the candidate may be presumed to have had sufficient training in process metallurgy to be active in this field at a level commensurate with the level of the degree granted.

If a thesis on a problem in foundry or welding metallurgy primarily involves chemistry or subject matter closely related to process metallurgy (e.g., solidification), the degree should be reported under process metallurgy.

A graduate degree in *Physical Metallurgy* may be presumed to be granted to a person whose thesis was concerned with a problem in the field of physical metallurgy. This field is defined as the science underlying the relation between the treatment, structure and properties of metals and the engineering applications of this science, especially to fabrication and heat treatment. Physical metallurgy by this definition includes the "physics of metals" (if the thesis is done in a department of metallurgy) and "mechanical metallurgy" (such as plasticity of metals, metal shaping, metal joining, powder metallurgy).

If a thesis on a problem in foundry or weld-

Table I — Degrees in Metallurgy

Year	Bachelors	Masters	Doctors
1948-49	...... *(738)*	197 *(197)*	42 *(34)*
1949-50	...... *(961)*	215 *(184)*	49 *(46)*
1950-51	...... *(802)*	210 *(238)*	56 *(40)*
1951-52	...... *(581)*	131 *(136)*	51 *(53)*
1952-53	...... *(550)*	124 *(126)*	69 *(56)*
1953-54	...... *(495)*	156 *(139)*	70 *(53)*
1954-55	474 *(449)*	161 *(146)*	74 *(62)*
1955-56	545 *(485)*	163 *(139)*	76 *(72)*

Figures in italics are from "Engineering Enrollments and Degrees, 1949" (and subsequent years), Office of Education, Federal Security Agency (1952 and after: U. S. Department of Health, Education and Welfare), Washington

Table II – Field of First Degree (B.S.) of Recipients of Graduate Degrees

Bachelors' Degree	Masters				Doctors			
	1954-55		1948-1955		1954-55		1948-1955	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Metallurgy	99	63.9	701	68.7	52	70.2	261	68.3
Mechanical Engineering	26	16.8	82	8.0	7	9.5	30	7.9
Chemical Engineering	17	11.0	79	7.7	5	6.8	35	9.2
Chemistry	7	4.5	53	5.2	3	4.0	26	6.8
Physics	2	1.3	42	4.1	6	8.1	21	5.5
General Engineering	—	—	17	1.7	—	—	4	1.0
General Science	1	0.6	13	1.3	—	—	—	—
Mining Engineering	—	—	11	1.1	—	—	1	0.3
Others	3	1.9	22	2.2	1	1.4	4	1.0
Total known	155	100.0%	1020	100.0%	74	100.0%	382	100.0%

ing metallurgy primarily involves physical metallurgy, the degree should be reported in this classification.

The questionnaire suggested that graduate degrees be reported separately for "process metallurgy" and "physical metallurgy", regardless of whether on not this distinction appeared on diplomas or otherwise.

Degrees in Metallurgy

The numbers of degrees granted each year are probably the most representative single measure of current activity in metallurgical education.

Such enrollment figures are useful for projecting short-term trends, but they are less definite because they contain an unknown fraction of part-time students. By contrast, the degrees granted measure formal educational efforts carried to completion. However, they should not be interpreted as being equal to the number of persons available for employment, since numbers of new Bachelors and Masters continue their studies, and some students obtaining graduate degrees are already employed or on leave from their positions.

Bachelors' Degrees in metallurgy granted in the United States are shown in Table I. The figures in italics starting with the academic year 1948-49 are taken from the annual government bulletins noted. For the two years of our survey, our figures are larger than reported in the government bulletins.

Figure 1 shows the numbers of Bachelors' degrees granted in all branches of education in the United States in engineering and in metallurgy each year since 1948-49. The logarithmic scale permits direct comparison of the rates of change on a percentage basis. The figures for all engineering and for metallurgy change at fairly similar rates, while the Bachelors' degrees granted in all fields are more stable.

It is likely that the number of Bachelors' degrees granted in metallurgy in 1956-57 increased somewhat over the preceding year. This increase and current enrollments suggest that the decline which began in 1950-51 has now run its course.

Graduate Degrees – Masters' and Doctors' degrees for the eight years starting in 1948-49 are also given in Table I. On the basis of the questionnaire they are shown in Fig. 2 in three categories – process metallurgy, physical metallurgy and "not differentiated".

The large annual totals of Masters' degrees in the post-war period were followed by a marked drop. In the last three years covered, the totals stabilized at a constant level. The Doctors' degrees continued their slight upward trend. If the graduate degrees are broken down into the categories of process metallurgy, physical metallurgy and "not differentiated", appreciable changes in these subdivisions appear from year to year.

Table I permits a comparison of the number of graduate degrees reported in this survey with the totals reported in Government publications. As for the Bachelors' degrees, the survey has again yielded many larger totals.

Only five Engineers' degrees in metallurgy

Table III – Foreign Students Receiving Degrees in Metallurgy

	1954-55			1955-56		
	Bachelors	Masters	Doctors	Bachelors	Masters	Doctors
Foreign students	6	18	5	13	19	10
Foreign students returning to home country	—	—	—	8	10	7

were granted by academic institutions in each of the academic years 1954-55 and 1955-56. This indicates the lack of numerical importance of this type of degree.

Other Aspects

Graduate Study in Metallurgy – The 1954-55 questionnaire included a query as to the field in which those receiving graduate degrees had obtained their Bachelors' degrees. Replies covering 155 out of 161 Masters' degrees and all 74 Doctors' degrees were returned. These data, together with seven-year totals for the period 1948-49 through 1954-55, are shown in Table II.

The large percentage of graduate students who took their undergraduate training in metallurgy may be noted. Mechanical and chemical engineering and to a lesser extent chemistry and physics also figure significantly, but the numbers of students entering metallurgy from these fields vary so much from year to year that only the seven-year totals should be considered.

Of the 74 Doctors' degrees granted in 1954-55, 56 or 75.7% went to persons holding Masters' degrees in metallurgy. The corresponding figures for the seven-year period 1948-55 are 274 or 71.7% with Masters' degrees in metallurgy.

Length of Study – The questionnaire for 1954-55 inquired about the length of study required for obtaining the various degrees. Only two institutions offered a full-time undergraduate curriculum in metallurgy as a five-year course. Six schools, located in urban or industrial centers, reported regular arrangements for part-time study toward the Bachelors' degree. The resulting increases in time required vary greatly.

Full-time Masters' candidates are reported to complete their studies in periods ranging from two terms to two academic years. Usually, this period, and especially its lower limit, increases by 50 to 100% if students hold research appointments within the institution and by several hundred percent if students are employed in industry.

The minimum time required for full-time study toward a doctorate is reported as two years, but most often it is three years. Research and other appointments and outside employment (where this is permitted) again increase the total time required; the reported increases differ widely among institutions.

Scholarship aid was the subject of a special survey which included Canadian institutions. The information dealt with scholarships received regardless of source, in 1955-56 by undergraduates majoring in metallurgy, and with scholarships specifically designated for students of metallurgy. Conditions are so complex and differ so much, institution to institution, that only a brief summary will be given here.

Out of a total enrollment of 2207 undergraduates covered by replies to the questionnaire, 400 or 18% received some form of scholarship aid. At most, 289 or 72% of these scholarships were specifically designated for students of metallurgy, while the balance came from general funds.

Half of the scholarships designated for students of metallurgy were supported by "foundations, technical societies, fraternal organizations". Industrial concerns supported directly about 40% of the scholarships; some, however, made contributions through foundations and such scholarships were not included in the figure of 40%. Only about 10% of the scholarships designated for undergraduates in metallurgy represented "endowment or other funds directly administered" by academic institutions, and funds granted by state or municipal bodies. Among the designated scholarships, about 12% provided \$50 to \$249 and about 41% \$250 to \$499 per year. About one-quarter carried stipends in the range of \$500 to \$749, while the remaining quarter received over \$750. There is reason to believe that frequently large grants, although reported as single scholarships, were actually distributed among several recipients.

Foreign Students – The numbers of foreign students receiving degrees in metallurgy are

Table IV – First Employment After Graduation in Two-year Period 1954-1956

First Employment	Bachelors		Masters		Doctors	
	Number	Percent	Number	Percent	Number	Percent
Industrial						
Operations	222	27.6	38	12.1	7	4.8
Research and development	144	17.9	104	33.2	82	56.6
Not differentiated	220	27.4	29	9.3	6	4.1
Academic						
Teaching	7	0.9	11	3.5	22	15.2
Research	18	2.2	10	3.2	8	5.5
Continued studies	89	11.1	70	22.4	1	0.7
Research institutes	13	1.6	10	3.2	9	6.2
Government	6	0.7	8	2.6	6	4.1
Military service	54	6.7	15	4.8	2	1.4
Other	31	3.9	18	5.7	2	1.4
Total	804	100.0%	313	100.0%	145	100.0%

given in Table III. The figures for 1955-56 also show the numbers of those returning to their home countries. The degrees accounted for in this manner are of the order of 2% of Bachelors' degrees and about 10% of graduate degrees. A deduction of 10%, therefore should be made in arriving at the number of persons with graduate training available for employment in the United States. The training of foreign students does not significantly interfere with the domestic supply since the capacity in many institutions exceeds enrollments, and some foreign students are added, at least temporarily, to the domestic supply of trained metallurgists.

Types of Employment

Table IV shows the types of employment or other activity entered into by recipients of degrees in metallurgy in the academic years 1954-55 and 1955-56. The samples tabulated amounted to 78.9, 96.6 and 96.7% for Bachelors, Masters and Doctors, respectively. This may be the first time that information on employment of metallurgists after graduation has become available.

Of the Bachelors 11.1% continued their studies; 22.4% of the Masters. Also, some of those entering employment with Bachelors' or Masters' degrees became part-time graduate students, but are not listed as such in Table IV. These groups are not the only source of advanced students in metallurgy. Each year a significant number of men leave industrial employment and undertake graduate studies. Nearly one-third of all graduate students entered metallurgy from other fields of undergraduate specialization.

Two-thirds of the Doctors are employed by industrial companies. The same applies to those Masters who do not continue their studies. An even larger fraction of those obtaining Bachelors' degrees enter industrial employment. Within the groups employed by industry, the fraction of those entering "operations" decreases as their degrees become more advanced. There is a corresponding increase in the fraction of those entering research and development.

Academic employment constitutes a significant proportion for persons with Doctors' degrees. Some of the individuals in this group may later leave academic employment. Only a smaller number can be expected to move in the reverse direction.

Employment by research institutes and the Government is nearly insignificant for new Bachelors. It becomes more important for those with higher degrees.

Conclusion and Forecast

The 1955 article arrived at a short-term forecast of 150 to 200 Masters' degrees and 60 to 80 Doctors' degrees per year. The figures for 1954-55 and 1955-56 fall within these ranges. At the present time, no revision in the forecast of Masters' degrees is indicated, while the expected range for Doctors' degrees should be raised slightly to 65 to 85 per year.

Major changes are most likely to occur in the undergraduate area, and it is safe at this time to predict increases. About 750 new Bachelors in metallurgy annually are probable in the immediate future and it seems entirely possible that in a few years this number will exceed 1000.

Alloys for Precious Metal Jewelry

*By RALPH H. ATKINSON**

Although an integral part of the broad field of metalworking, the precious metal jewelry manufacturing industry has developed its own unique materials and processes. Here the author describes the metals most frequently used by that industry. (Tgs, 17-7; Au, Ag, EG-c)

In the "Census of Manufacturers" (1954) the precious metal jewelry category includes jewelry and other articles, to be worn or carried on the person, made of precious metal with or without precious stones, including cases and lighters, vanity cases and compacts, trimmings for umbrellas and canes, and jewel settings and mountings. "Precious metal", in addition to solid gold and the platinum metals, includes filled gold, rolled gold plate, filled palladium, rolled palladium plate, and sterling silver. Base metals electroplated with gold, rhodium or silver are included in "costume jewelry".

For purposes of the Census the precious metal jewelry industry has three main divisions:

1. Manufacturing of jeweler's findings.
2. Cutting and polishing of precious and semiprecious stones (lapidary).
3. Manufacture of articles of jewelry.

In the above classification jewelers' findings include stock-shop products such as sheet, wire and tubing for use in the manufacture of jewelry (46% of total in 1954), unassembled jewelry parts (36% of total) and machine chain (16% of total). However, those in the trade restrict the term "findings" to unassembled jewelry parts.

The relative size and importance of the industry as a whole, and its divisions, can be gaged from the statistics given in Table I. Of the total employed in the manufacture of jewelry, approximately 29,000 can be considered as engaged in a metal industry. Small establishments are the rule; only one in 40 has more than 100 employees and only one company has more than 1000 employees. Eighty percent of the precious metal jewelry is made in four states: New York, New Jersey, Massachusetts and Rhode Island. Principal manufacturing centers are New York City, Providence, Attleboro and Newark.

Precious Metals for Jewelry

In Table II an attempt has been made to assemble data and estimates for the amount and value of the different metals used for jewelry in the year 1954. That year was chosen so metal data will be comparable with the census data given in Table I. The jewelry industry consumed 70,846 oz. of platinum metals of an estimated value of $4,600,000 in 1954. The latter year, however, appears to have been an off year, because the average annual consumption of platinum metals for jewelry for the period 1941-52 was 114,000 oz. with an estimated value of $7,700,000. In the absence of official data, it is necessary to make estimates of the annual consumption of the other metals, including gold, which continues by far to be the most important jewelry metal. It is estimated that in 1954 consumption of gold was 1,000,000 oz., approximately 45% of the total gold used by U. S. industry that year. The estimate is probably reasonable, because two rings for each of the

*Now retired, Mr. Atkinson was a metallurgist at International Nickel Research Laboratory. He resides in Westfield, N.J. This is the first of a series of four articles on jewelry manufacture.

1,500,000 brides married each year in the U.S. would require about 300,000 oz. of gold without taking other jewelry into account. Estimated consumption of silver at 500,000 oz. could be too low because silver jewelry is sold by chain stores as well as by retail jewelers. Manufacture of precious metal jewelry also requires significant amounts of base metals, chiefly as foundation metal of gold-filled and rolled gold plate. Base metals used include nickel, with an estimated annual consumption of 500,000 lb., copper (200,000 lb.) and zinc.

Table I – 1954 Census Data for Precious Metal Jewelry Industry

	Findings	Lapidary†	Jewelry
Number of employees	5,371	1,759	23,455
Number of plants	234	333	1,327
Manufacturing cost*	31.4	10.6	145.6
Cost of materials*	38.0	23.0	112.6
Value of shipments*	69.4	33.6	258.1

*In millions of dollars.

†Lapidary shipments include jewelry diamonds ($18.4 million) and industrial diamonds ($5.1 million).

Values for the platinum metals rest on a broad basis of proved industrial uses. Jewelry accounts for only 25% of the consumption of these metals; in addition they have well-established uses in the chemical, electrical and dental fields. For instance, in the period 1941 to 1952, 45% of the palladium was taken for electrical uses, chiefly for the contacts of telephone relays. For platinum, an important new use has developed in the so-called "platforming" process for upgrading gasoline and it has also become a key metal in the manufacture of fiber glass.

Commercial Standards and Stamping Laws

Although there are no specifications in the ordinary sense for jewelry metals, it has long been customary to use a marking system to guarantee quality of silver and gold and thereby guard against fraud. London instituted a hall mark for silver and gold plate as long ago as 1300 A.D. In America the situation is complex because both Federal and State Governments are concerned with the quality of jewelry metals. In 1950, for instance, in addition to the National Stamping Act, 24 states had stamping laws for silver, 17 for karat gold and 5 for platinum. There are also commercial standards, promulgated by the National Bureau of Standards, for karat gold, gold-filled and rolled gold plate articles, silver in combination with gold, articles made wholly or in part of platinum, jewelry and novelties of silver. The principal composition requirements for silver, gold, platinum and palladium are summarized in Table III.

Two grades of silver are recognized for stamping purposes, namely, "sterling silver" (92.5%) and "coin silver" (90%). The stamping laws permit gold of any karat from 10 karat (41.65%) to 24 karat (100%) to be stamped, but in practice the popular jewelry grades are 14, 12, 10 and 18 karat in that order. "Karat gold" means not less than 10-karat gold, but a tolerance of one-half karat is allowed, or a tolerance of one karat if solder is used.

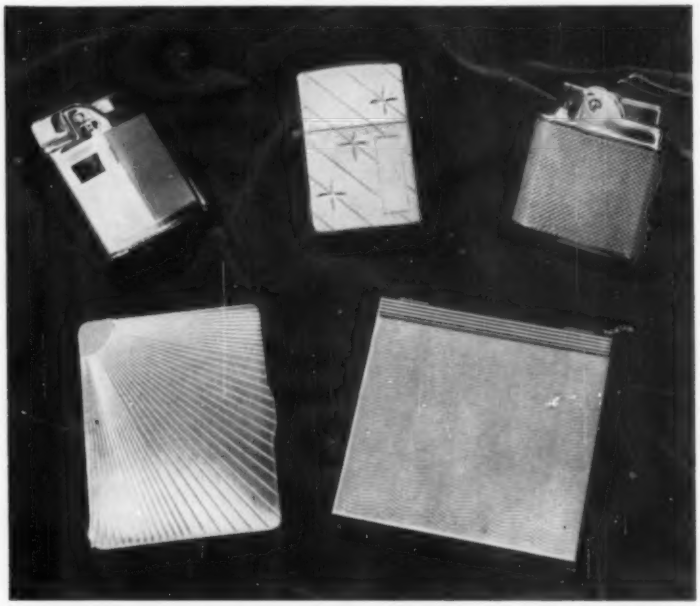
Stamping laws for platinum are complex due to a desire to make provision for stamping not only of platinum but also its alloys with the other metals of the platinum group. There has probably been some reluctance to write laws which might hinder development of a relatively new jewelry metal. As stamping laws stand at present, an article can be marked "platinum" if it contains at least 98.5% platinum group metals, of which platinum must be at least 93.5%. Provision is also made for the stamping of platinum alloys such as 90% platinum, 10% iridium; 80% platinum, 20% iridium; and 90% platinum, 10% rhodium, which have been developed to meet the need for hard jewelry platinum of high quality. The stamping laws and commercial standards for platinum are probably not yet in final forms. Proposals are currently under consideration for raising the minimum platinum content and lowering the tolerance in these alloys.

As a jewelry metal, palladium is even newer than platinum and the stamping requirements dealing with it are less developed. How-

Table II – U.S. Consumption of Metals for Jewelry During 1954

Metal	Weight	Price	Value
*Gold	1,000,000 oz.	$35 per oz. (Troy)	$35,000,000
Platinum	37,749 oz.	$90	3,400,000
Palladium	27,408 oz.	$21	575,000
Iridium, rhodium ruthenium, osmium	5,689 oz.	$115	655,000
*Silver	500,000 oz.	85c	425,000
*Copper	200,000 lb.	30c per lb.	60,000
*Nickel	500,000 lb.	65c per lb.	325,000

*Estimated



ever, in New Jersey an article may be marked "palladium" if it contains a minimum of 95% palladium; elsewhere the stamping position of this metal is not clearly defined.

The quality control system operates very simply. The manufacturers apply the quality marks themselves. Hitherto the industry has done its own policing through a Vigilance Committee. "Trade Practice Rules for the Jewelry Industry", recently issued by the Federal Trade Commission, will help further in maintaining standards.

Composition and Mechanical Properties

The composition and mechanical properties of some jewelry alloys are given in Table IV. This presentation is primarily for metallurgists, because jewelry manufacturers, in contrast to other metal fabricators, show little interest in detailed composition or mechanical test data for their alloys. They seek metals with adequate strength and hardness in the annealed condition, and with good ductility and solderability.

Platinum and palladium, like gold and silver, are too soft to be used as the pure metals and it is customary to alloy them with other metals of the platinum group. Popular jewelry alloys include 95 platinum, 5 iridium; 90 platinum, 10 iridium; and 95.5 palladium, 4.5 ruthenium. Ordinary jewelry platinum (95%) and palladium (95%) in the annealed condition have tensile strengths from 40,000 to 50,000 psi., hardness of Brinell 85 to 90 and elongation of 25%.

Gold jewelry alloys are divided into colored golds and white golds. Alloying metals modify the natural yellow gold color of pure gold; copper gives a red shade, silver a green tone, and nickel, palladium and zinc have a whitening effect. The effect of composition on color can be seen in the 14-karat golds included in Table

Table III – Stamping Law Requirements for Composition of Jewelry Alloys

Jewelry Metal	Content	Alloying Elements
Silver, sterling	92.5%	Unspecified
Silver, coin	90.0	Unspecified
Gold, 18-karat	75.0	Unspecified
Gold, 14-karat	58.35	Unspecified
Gold, 12-karat	50.0	Unspecified
Gold, 10-karat	41.65	Unspecified
Platinum (if solder is not used)	93.5 to 98.5*	1.5% Unspecified
Platinum (if solder is used)	90.0 to 95.0*	Up to 3.5% solder; 1.5% Unspecified
Palladium	95.0†	Unspecified

*The range of permissible platinum content exists because up to 5% of platinum can be replaced by other metals of the platinum group — palladium, rhodium, iridium, ruthenium or osmium.

†Minimum content specified in the New Jersey Stamping Law.

IV. Yellow is the most popular of the colored golds; there are several 14-karat yellow golds, a typical one having the composition 58.3% gold, 10.4% silver, 29.1% copper and 2.1% zinc. The other colored golds, which are used to get special decorative effects, are of relatively minor importance. The lower quality golds (10 and 12 karat) are used for making gold filled and rolled gold plate articles. Colored golds in the annealed condition have tensile strengths from 60,000 to 80,000 psi, hardness numbers from Brinell 85 to 180, and 30 to 50% elongation. White golds are almost as popular as yellow gold in some areas. The usual white gold is a quaternary alloy containing nickel, zinc and copper, which is substantially stronger and harder than yellow gold. Its tensile strength is about 100,000 psi., hardness Brinell 200 to 250, and elongation about 45%. Palladium-containing white gold has been used for hand-made jewelry, but can never be popular because it costs more than the other white golds of the same karat; it lacks the strength and hardness of the nickel-containing white gold. It has a higher melting point and is preferred where much soldering has to be done.

There is little, if any, systematic metallurgical control in the manufacture of jewelry, although the primary fabrication by the refiners is carefully controlled. The manufacturer relies on traditional methods with occasional advice from the refiners who supply his metals. Wherever

Table IV – Composition and Mechanical Properties of Jewelry Alloys*

Metal	Au	Ag	Cu	Ni	Zn	Other	Tensile Strength	Elong. in 2 In.	Brinell Hardness
Platinum, 95.0%	—	—	—	—	—	5 Ir	40,000 psi.	25%	90
Platinum, hard, 90.0%	—	—	—	—	—	10 Ir	55,000	25	130
Palladium, 95.5%	—	—	—	—	—	4.5 Ru	54,000	25	85
Colored golds									
18-karat yellow	75.0	15.0	10.0	—	—	—	67,000	42	125
14-karat red	58.3	—	41.7	—	—	—	57,000	50	85
14-karat pink	58.3	4.9	31.6	5.2	—	—	82,600	42	170
14-karat yellow	58.3	20.8	20.8	—	—	—	77,000	34	180
14-karat yellow	58.3	10.4	29.1	—	2.1	—	—	40	—
14-karat green	58.3	30.0	6.0	1.5	4.2	0.1 Mn	80,400	32	—
10-karat yellow	38.5	15.4	41.9	1.2	3.1	—	83,300	34	—
10-karat yellow	41.2	8.8	42.1	1.6	5.8	—	—	—	110
White golds									
18-karat	75.0	—	3.5	16.5	5.0	—	100,800	47	245
18-karat	75.0	—	—	—	—	25 Pd	44,000	—	76
14-karat	58.3	—	16.0	17.0	8.6	—	105,000	43	206
Silver									
Sterling	—	92.5	7.5	—	—	—	37,400	42	50
Coin	—	90.0	10.0	—	—	—	40,000	—	60

*Mechanical properties are approximate values in the annealed condition.

possible full advantage is taken of work hardening to improve wear properties, but where soldering has to be done at a later stage there will be local annealing. Metallurgically the gold alloys are interesting because many of them are age hardenable by a mechanism depending on the arrangement of gold and copper atoms. Although this property of the gold-copper alloys has been utilized in the dental field for more than 50 years, few jewelers appear to have felt a need to increase the strength and hardness of their metals by age hardening. Actually the demand for hard jewelry metals is relatively small because mechanisms, springs, and other internal parts do not have to conform to Stamping Laws and consequently are made of base metals. Although age hardening would be possible for certain articles, it obviously would not be applicable to articles set with precious stones.

Both the workability of palladium and its suitability for *objets d'art* are well demonstrated by the Baker Palladium Perpetual Trophy for the International Grand Prix Power Boat Race, shown alongside.

[In subsequent articles, Mr. Atkinson will discuss other aspects of precious metal jewelry manufacture. Among the subjects to be covered are special fabricating techniques and precision casting methods.]

This palladium trophy required the use of many of the jeweler's arts and techniques. (Courtesy International Nickel Co.)

Correspondence...

Corrosion Test Sites Needed

Wilmington, Del.

A task group of the Welding Research Council (High Alloys Committee), has undertaken a field corrosion test program to determine what industrial plant mediums are specific in causing intergranular corrosion of stainless steel. Intergranular corrosion in both wrought and cast steels is sometimes called "sugaring" because whole grains can be rubbed from the surface; when present adjacent to welds, it is known as "weld decay".

It is well known that unstabilized austenitic stainless steels such as Types 304 and 316 can be rendered susceptible to intergranular attack by heating into the range of 900 to 1400° F. This susceptibility has been related to carbide precipitation and can be brought about by exposure in this temperature range for times as short as those encountered in welding (seconds).

Susceptibility to intergranular corrosion can be appraised by exposure in such test mediums as boiling 65% nitric acid, acidified copper sulphate solution, and a mixture of nitric and hydrofluoric acids. These tests can often predict whether or not specific lots of steel may be intergranularly corroded if installed under service conditions which are known to produce this type of attack. The present program is aimed at obtaining more information on the character of process mediums which will cause this type of attack.

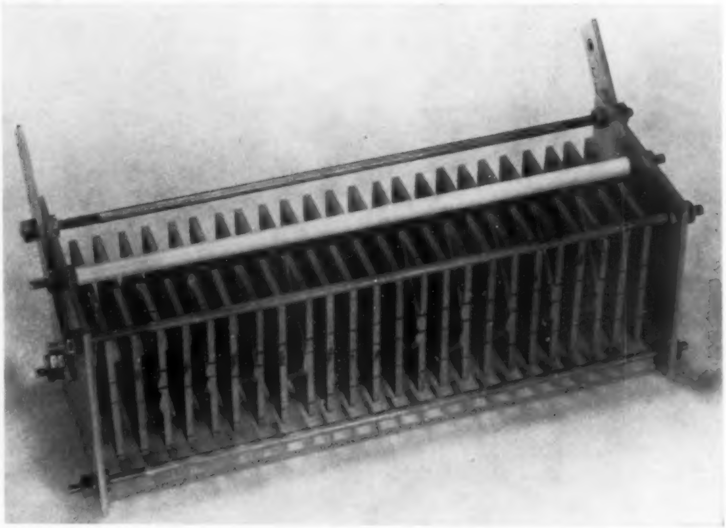


Fig. 1 – Test Rack Containing 20 Specimens of Type 304 or 316 Stainless

Included in the list of commonly encountered mediums known to cause intergranular corrosion of susceptible steels are sulphuric, acetic, formic, and some of the fatty acids, in addition to the test solutions listed above. A fairly wide area of ignorance exists concerning other solutions which might cause this type of attack. In approaching new problems, therefore, the user of the steels has two choices. The first involves "taking a chance" and gambling that intergranular corrosion will not occur in plant equipment assembled in the conventional manner. The price of this approach is possible plant shutdown, lost production, and equipment replacement. The second alternative is to "play it safe" and pay a premium for stabilized or low-carbon alloys. This premium is reflected directly in plant investment.

To partially close this gap, the task group has prepared several hundred corrosion test racks for exposure under a wide variety of conditions and locations. Two series of racks have been prepared as illustrated in Fig. 1, one series carrying specimens of Type 304 stainless steel and the other Type 316. The racks carry approximately 20 specimens each, which represent the range of intergranular corrosion susceptibility from the fully annealed condition through partially and severe sensitization as caused by conventional welding and stress-relieving heat treatments. Welded specimens, Fig. 2, include "as deposited" weld beads prepared at several welding heats as well as

Corrosion Testing . . .

some welds that have been stress-relieved. The specimens have been carefully heat treated and tested in standard corrosion test mediums, and their pedigrees recorded.

A search for test sites is now in progress. Exposure locations are desired where the racks (which are approximately 6 × 12 in.) can be securely fastened in the process medium. Exposure conditions should remain reasonably constant for at least a year. Those interested in cooperating in this program are invited to submit a description of the exposure site including the solution composition and local exposure conditions. Specific process details are not necessary. If and when results are published, appropriate acknowledgment will be made.

Fig. 2 — Welded Specimen, Ready for Insertion in the Test Rack

This program should make it possible to spell out more adequately the characteristics of process mediums which will cause intergranular corrosion, and what level of resistance to this type of attack, as measured by conventional tests, is necessary for effective utilization of the austenitic stainless steels.

Those interested in cooperating in this project should write to the chairman of the task group, as shown below.

W. B. DeLong
E. I. duPont de Nemours & Co., Inc.
Engineering Dept.,
Experimental Station,
Wilmington 98, Del.

(*More correspondence on p. 116*)

MOLY NEWS

CLIMAX MOLYBDENUM COMPANY, 500 FIFTH AVENUE, NEW YORK 36, N. Y.

Ultra-Strength Steels Boost Tensile Strengths to 300,000 psi.

Ten years ago, engineers considered 180,000-psi tensile strength in steels the maximum they could use safely.

Today, alloy steels with minimum strengths of 220,000 to 300,000 psi are being used commercially. These ultra-strength steels have the ductility and toughness needed for structural applications. At tensile strengths above 220,000 psi, they show more strength per pound of product than high-strength aluminum alloys. And at 260,000 psi, they are approximately 15% lighter than aluminum alloy products of the same strength.

Molybdenum is an essential element in almost all of these steels.

How are the higher strengths and strength/weight ratios of these steels being used? Until recently, they've been utilized almost exclusively in aircraft components, such as landing gear. Now, however, they're being considered wherever weight and space savings compensate for higher fabrication costs . . . as, for example, in equipment that must be moved (portable tools); gears, pulleys, belts, liners; heavy machinery operating at high stresses; machinery where inertia is a design factor; materials-handling equipment, such as cranes; and transportation equipment.

Like to know more about ultra-strength steels and their properties, and the names of manufacturers? For our free booklet, circle #1 on the coupon.

Bulletin Shows How to Get Heat Resistance in Cast Iron

In cast iron, heat resistance can mean different things: resistance to growth, to heat checking, to scaling, or to deformation under load at high temperatures.

"Why Moly Iron? #5" contains a chart showing the specific kinds of heat resistance needed by parts such as brake drums, melting pots, piston rings and so on. This chart also lists the best type of iron to use and the proper alloy additions. A number of detailed case histories document this useful bulletin.

For a free copy of "Why Moly Iron? #5" circle #2.

New Coatings May Solve Moly's Oxidation Problem

The most important obstacle to using molybdenum at high temperatures is being overcome. Oxidation is the problem; at temperatures over 1000F, molybdenum oxidizes rapidly.

Newly developed coatings offer molybdenum the needed protection. Three types are promising:

1. Electro-deposited chromium and nickel layers which protect molybdenum to 2000F.
2. Sprayed coatings of aluminum-chromium-silicon alloys, and nickel-boron alloys, which have proved effective at 2000-2400F.
3. Ceramic and molybdenum disilicide coatings which hold promise of protecting molybdenum from oxidation at even higher temperatures.

Digested from "Protecting Molybdenum at High Temperatures" by Julius Harwood, Materials & Methods. For reprint of entire article, circle #3.

Booklet Deals with Molybdenum Joining Techniques

Recent progress in joining molybdenum, and suitable means for protecting it from oxidation, are opening up new uses for molybdenum and its alloys in structural components for high-temperature service.

"A New Look at Joining Molybdenum" by R. R. Freeman and J. Z. Briggs, both of Climax, analyzes the factors involved in joining moly and discusses the methods available.

For the free booklet, circle #4.

List of Moly Literature Now Available

Copies of more than 30 recent pieces of technical literature on molybdenum are available from Climax Molybdenum Company. *For a free list of these, including titles, authors, sources and 25-30 word summaries, just circle #5.*

Steels for Power-Plant, Refinery Equipment at 900-1100F

Designers of power-plant and refinery equipment who need to select steels for applications at 900 to 1100F will be interested in a copy of "Chromium-Molybdenum and Chromium-Molybdenum Vanadium Steels for power-plant and refinery service up to 1100F."

This paper, presented at the ASME annual meeting by George V. Smith, Bard Professor, Cornell University, appraises literature on the subject and draws some new, objective conclusions.

For a free reprint, circle #6.

New Climax Alloy Proves Unusually Wear Resistant

These liner castings, made of Climax 321, proved highly resistant to wear in our ball mill discharge launders. Severe wear normally occurs in this operation as a result of erosion from the coarse pulp flowing out of the ball mill discharge.

If you need a highly wear-resistant material, you may be interested in our new Climax 321 Alloy. It's a hard, martensitic type of white iron containing nickel, chromium and molybdenum in proportions that are well balanced, both metallurgically and economically.

We've been using 321 Alloy in our own mining operations with exceptional results. Comparative tests in ball mill liners and grinding balls proved its excellent wear-resisting properties.

Because this alloy is relatively new, service results in other applications are not yet available. However, our laboratory studies and data indicate it should prove suitable for the general run of abrasion-resistant castings of the martensitic white iron type—such as wear shoes, sand and dredge pump wearing parts, pug mill knives, mixer liners, etc.

Climax 321 can be melted in a cupola or electric furnace and cast in either sand or permanent (chill) molds. It has a normal hardness range of 55 to 62 Rockwell "C".

Composition: Carbon 3.30-3.60%; Silicon 0.30-0.60; Manganese 0.50-0.80; Nickel 2.75-3.25; Chromium 1.75-2.25; Molybdenum 0.70-1.10; Sulphur 0.15 max.; Phosphorus 0.30 max. *For data sheet, circle #7.*

Climax Molybdenum Company, Dept. 5
500 Fifth Avenue, New York 36, N. Y.

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City____________________

Termites in the Lattice

MELBOURNE, AUSTRALIA

We have often tried to convince newcomers to the science of metallurgy that the weakness of metal components under some conditions is caused by termites in the lattice. Indeed, some failures appear to be explicable in no other way. However, it was not until we applied the technique of multiple-beam interferometry to the problem that we were able to actually see one of these destructive little beasts in some super-purity aluminum. Under normal illumination all that could be seen was a pit which we had erroneously attributed to faulty electropolishing. As the illustration shows, this was obviously a burrow which the *termes metallurgica* was making.

A Multiple-Beam Interferogram of Electropolished High-Purity Aluminum. 150 ×

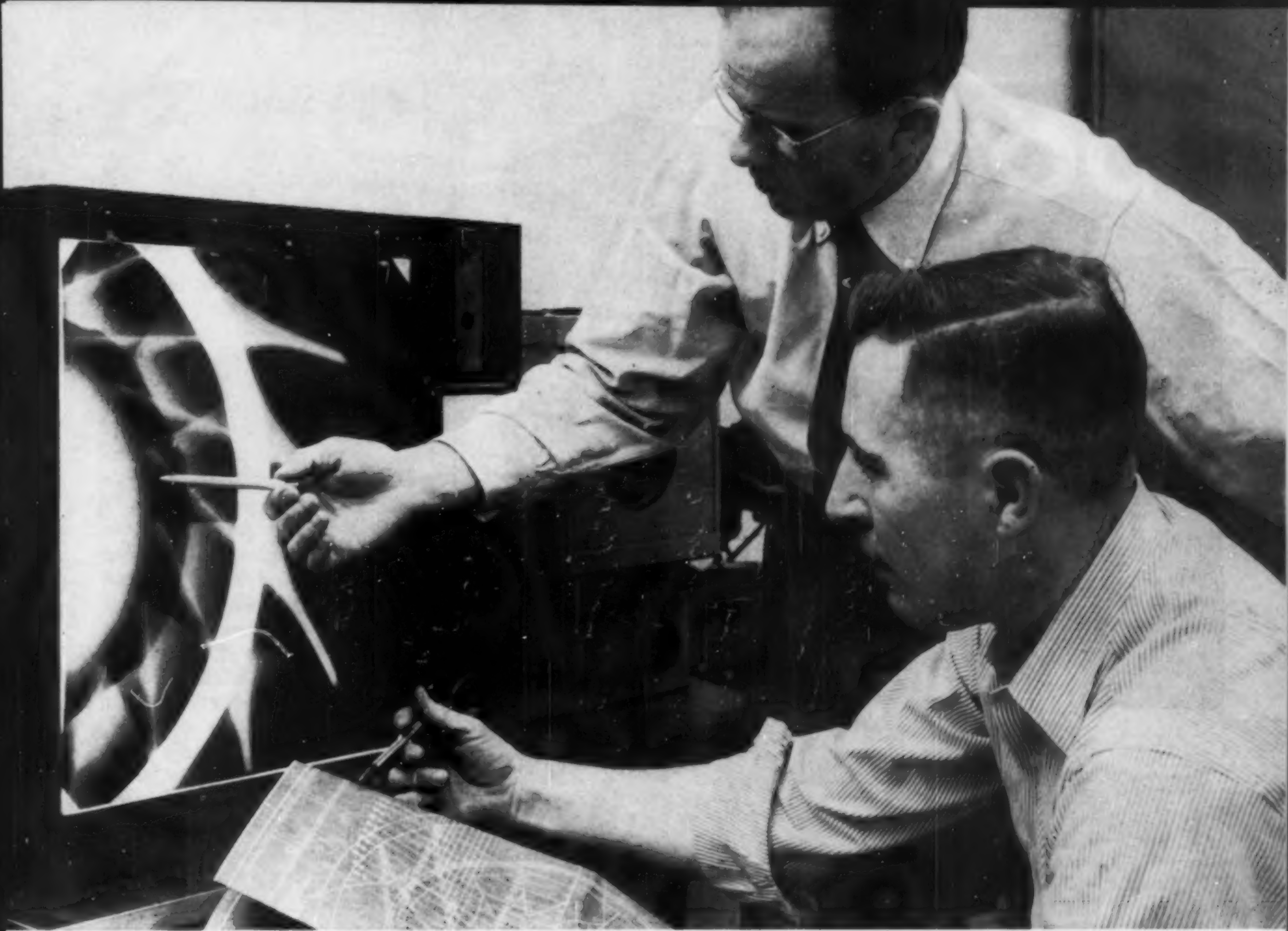
R. C. GIFKINS
Physical Metallurgy Section
Commonwealth Scientific and
Industrial Research Organization

Effect of Lead on Steels

(Confession of Error)

In digesting an article on the above topic by W. E. Bardgett, research manager of the United Steel Companies Ltd. of England, George F. Comstock, our reviewer, wrote:

"Satisfactory service has been rendered by leaded steel in motor cars, etc., because the conditions of very high tensile strength with absence of notches (where lead is appreciably detrimental to fatigue



At the viewer examining a radiograph of a large impeller fan are Mr. Edward Young, Supervisor of Quality Controls (seated), and Mr. Russell H. Hollister, Vice-President, Sales, Morris Bean & Company.

"Inspection of our intricate aluminum castings needs the latitude of DuPont x-ray film"

says Mr. Edward T. Young, Supervisor of Quality Controls, Morris Bean & Company, Yellow Springs, Ohio

In the x-ray room at Morris Bean's foundry, Du Pont Technical Representative, E. R. Baron, discusses a typically intricate Antioch Process casting with Alfred C. Brightman, radiographer.

Morris Bean & Company specializes in a plaster mold method of casting aluminum, known as the Antioch Process. The castings are strong, remarkably smooth and usually intricate in shape. Metal thickness often varies greatly within one casting.

Du Pont Type 506 N.I.F.* x-ray film is the company's choice for x-ray inspection of these complex castings. Says Mr. Young: "This film has the latitude that's essential in examining 'thick-and-thin' castings. It has the resolution needed to reveal even the smallest cracks, traces of porosity or oxide films.

"We radiograph every critical casting. The consistency of Du Pont film makes it easy to use standard exposures and saves us having to worry about 'reshooting'.

"Furthermore," concludes Mr. Young, "all problems in both supply and use of the film are given prompt attention by the Du Pont Technical Representative. This kind of service means a great deal to us."

For more information about this outstanding combination of x-ray film and technical service, contact the nearest Du Pont Sales Office or write Du Pont, Photo Products Dept., 2420-2 Nemours Bldg., Wilmington 98, Delaware. In Canada: Du Pont Company of Canada (1956) Limited, Toronto.

*Non-Interleaved Film

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Films..."Patterson" Screens...Chemicals

Lead in Steel . . .

resistance) very rarely occur in engineering practice."

This was intended to summarize Mr. Bardgett's conclusion, which was:

"It would seem, therefore, that the conclusions go far to explain why, in spite of some past misgivings in respect of the fatigue properties of lead-treated alloy steels, thousands of tons of such steels have already given very satisfactory service in motor car and other components. Only at high levels of tensile strength, and where no stress raiser is present, does the presence of lead give rise to any substantial lowering of the rotary bending fatigue strength of these alloy steels, and very rarely is it that such conditions arise in engineering practice."

Unfortunately in editing the digest, both Mr. Bardgett and Mr. Comstock were made to say something quite incorrect, namely:

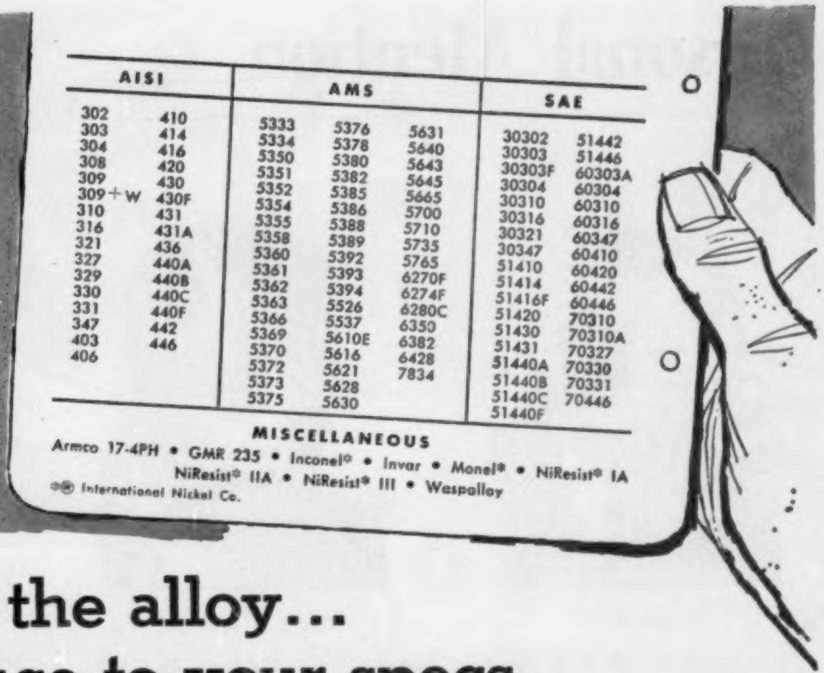
"Satisfactory service has been rendered by leaded steel in motor cars, because of the absence of notches in high tensile strength steel."

Mr. Bardgett in a recent letter to the Editor points out again that actually, lead has no effect on the values of limiting fatigue stress in the presence of a notch at the various tensile levels investigated, and only at high levels of tensile strength, and where no stress raiser is present, does the presence of lead give rise to any substantial lowering of the rotary bending fatigue strength of the alloy steels tested, and very rarely is it that such conditions arise in engineering practice.

Correction

In a book review entitled "The Metallurgy of Zirconium", (July 1957, p. 77), *Metal Progress* erroneously stated "The Metallurgy of zirconium is approximately 2 years old." This should have read "'The Metallurgy of Zirconium' [title of the book] is approximately 2 years old." Since there are several references in Mr. Goldman's review to the use of zirconium some years ago it is presumed that the readers will have recognized the above as a regrettable typographical error.

This alloy "shopping list" saves many a day for busy metallurgists!



AISI		AMS			SAE	
302	410	5333	5376	5631	30302	51442
303	414	5334	5378	5640	30303	51446
304	416	5350	5380	5643	30303F	60303A
308	420	5351	5382	5645	30304	60304
309	430	5352	5385	5665	30310	60310
309+W	430F	5354	5386	5700	30316	60316
310	431	5355	5388	5710	30321	60347
316	431A	5358	5389	5735	30347	60410
321	436	5360	5392	5765	51410	60420
327	440A	5361	5393	6270F	51414	60442
329	440B	5362	5394	6274F	51416F	60446
330	440C	5363	5526	6280C	51420	70310
331	440F	5366	5537	6350	51430	70310A
347	442	5369	5610E	6382	51431	70327
403	446	5370	5616	6428	51440A	70330
406		5372	5621	7834	51440B	70331
		5373	5628		51440C	70446
		5375	5630		51440F	

MISCELLANEOUS

Armco 17-4PH • GMR 235 • Inconel* • Invar • Monel* • NiResist* IA
NiResist* IIA • NiResist* III • Waspalloy

*® International Nickel Co.

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THE watchword of CANNON-MUSKEGON is "CONTROL." Careful selection of the finest raw materials . . . rigid melting procedures . . . complete chemical and physical testing facilities, plus closely supervised handling — produce alloys to your most exacting standards. More than 100 special and standard alloy analyses are produced each year.

The alloy list above is typical of production "regulars" for scores of users in all industrial fields. If you don't see what you need — remember, our facilities are open to "tailor" alloys to your specific needs. We'll also recommend proper in-plant handling and heat treating procedures to assure the desired physical and chemical properties in your final product.

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MASTER MET — CERTIFIED ALLOYS FOR INDUSTRY

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METALLURGICAL SPECIALISTS

Personal Mention

Ted Du Mond

TED DU MOND is the newest member of the rapidly expanding staff of the Metals Engineering Institute. Mr. Du Mond will act as editor-in-chief of the educational courses prepared by the Metals Engineering Institute and, in addition, will be secretary of the Special Engineering Program Committee. As secretary, he will be responsible for all engineering and production sessions presented before regional and national meetings of the American Society for Metals, with the exception of the technical sessions at the National Convention, where the *Transactions* papers are presented.

A graduate of the University of Cincinnati, Mr. Du Mond has devoted his time primarily to the field of technical writing and editing, specializing in engineering materials. After a few years with the technical editorial service of Westinghouse Electric Corp. and in the sales department of George Gorton Machine Co., he joined McGraw-Hill Publishing Co. in 1940. In 1945 he became editor of *Materials and Methods*, and held this position until joining the staff.

Mr. Du Mond is an active member of many technical societies, in addition to the American Society for Metals, and has appeared as guest speaker at many local chapter meetings. He is the author of two books and more than 100 technical articles.

Henry H. Hausner

HENRY H. HAUSNER, internationally known for his work in powder metallurgy and nuclear engineering, is continuing his pioneering work on powder metallurgy as vice-president of the nuclear engineering division of Penn-Texas Corp., New York City, and has started a program on research and development of the metal powder slip casting process, under an Atomic Energy Commission contract.

He received his metallurgical education in Vienna and later took charge of the laboratory of Elix A. G. there, one of Austria's leading incandescent lamp factories. As a result of his work with tungsten wire in lamps and electronic tubes, his interest was particularly focused on the fabrication and recrystallization of tungsten and molybdenum.

Immigrating to America in 1940, he worked with American Electro Metal Corp. for three years and then joined General Ceramics and Steatite Corp. as chief engineer. Here he attempted to combine ceramics and metals, and as a result published one of the first papers on "cermets". Turning from cermets to powder metallurgy, he investigated the powder metallurgy of reactor metals at Sylvania Electric Products Corp., in Bayside, L.I., until coming to Penn-Texas.

Dr. Hausner also finds time to act as adjunct professor at the Polytechnic Institute of Brooklyn and as consultant to several firms both here and abroad, including Argonne National Laboratory. He has also just edited a new book, "Powder Metallurgy in Nuclear Engineering". He is active in technical societies not only in this country but abroad as well, and only last year was elected vice-president of the International Plansee Society for Powder Metallurgy of Reutte, Austria.

T. E. Olson has formed the T. E. Olson Co. in Birmingham, Mich., to provide metallurgical and engineering sales representation to industry in Michigan. For the past ten years, Mr. Olson has been a sales representative with the Tocco Div. of the Ohio Crankshaft Co. He served as chairman of the Detroit Chapter in 1953.

Adolph J. Lena has been promoted to the newly created position of manager of the basic research department, Allegheny Ludlum Steel Corp., Brackenridge, Pa. Before his new assignment, Dr. Lena was associate director of research in charge of the physical metallurgy section.

Jay DeEulis has joined the industrial public relations firm of National Editorial Services as full partner and editorial director. For the past five years, Mr. DeEulis directed press relations and publicity activities as manager of press relations for the Carboloy Dept. of General Electric Co. in Detroit. He has also served as engineering editor of *Steel* and editor of *New Equipment Digest*, both published in Cleveland.

Thomas I. McClintock has been transferred from the Pittsburgh plant of the Aluminum Co. of America to the Alcoa plant at Vernon, Calif., where he will work under **Roy E. Paine**, past chairman of the Los Angeles Chapter.

Harry M. Alworth, Jr., has accepted a job as technologist in the sheet products division of the Applied Research Laboratory, U.S. Steel Corp., Monroeville, Pa. Mr. Alworth, a 1950 graduate of the University of Pittsburgh, was a metallurgist at the Gary, Ind., plant of the National Tube Div. of U.S. Steel before transferring to the Monroeville Laboratory.

Personals . . .

Earl W. Coleman is serving in the U.S. Navy for six months on the critical skills program. He is now stationed at Anacosta Naval Receiving Station, Washington, D.C., in the Naval Research Laboratory.

John T. Milek, formerly senior research engineer for North American Aviation, Inc., is now with Litton Industries, Beverly Hills, Calif., working on materials and process engineering as applied to manufacture of electronics components.

John W. Buskie has been elected vice-president of Tennessee Products & Chemical Corp., Nashville, Tenn., a division of Merritt-Chapman & Scott Corp. Mr. Buskie joined the company in 1954, and since 1955 has served as vice-president of a subsidiary, Tenn-Tex Alloy & Chemical Corp. More recently, he was named assistant vice-president of Tennessee Products & Chemical Corp.

Samuel E. Tyson, has been appointed metallurgist, stainless steels, for the Carpenter Steel Co., Reading, Pa. Mr. Tyson began his career at Carpenter as a laboratory assistant after his graduation from Pennsylvania State University in 1948, and was promoted to assistant metallurgist, stainless steels, in 1955.

W. B. Jones has been promoted to the post of sales manager, agricultural products, for the Crucible Steel Co. of America, Pittsburgh. For the past five years, Mr. Jones had been supervisor of agricultural sales at the company's Chicago sales branch, and prior to that time had been a sales service engineer at the Chicago branch.

Walter H. Langford has been transferred to the Longview Tex., installation of R. G. LeTourneau, Inc., as director of metallurgy. Mr. Langford, who joined LeTourneau in 1938, was formerly assigned to the Vicksburg, Miss., plant.

Harry B. Burrack has been named technical superintendent of the new Olin Mathieson Chemical Corp. aluminum plant in Monroe County, W. Va. Mr. Burrack, who has had 20 years experience in various phases of the aluminum industry, joined Olin Mathieson in 1955.

OHIO STEEL FOUNDRY CUTS COSTS MORE THAN 50% WITH NUCLEAR SYSTEMS' RADIOGRAPHY MACHINES

Art Gross, chief metallurgist of Ohio Steel Foundry Co., Springfield, Ohio, states that by using two radiography machines designed and manufactured by Nuclear Systems, a division of The Budd Company, approximately 3000 "shots" a month are made in testing castings of various sizes and shapes.

"By exposing a number of castings at one time," said Mr. Gross, "Ohio Steel has cut operating costs to less than half of what we'd spend if we used X-ray equipment. Also, if we used X-ray, we'd require 50% more people on the job to maintain safety from exposure.

"Using Nuclear Systems' models 10 (shown above) and 50, we keep the machines in use 24 hours a day checking production fittings such as valves, elbows and tees. To control quality we radiograph about 10% of this type equipment."

Nuclear Systems manufactures a complete line of gamma radiography machines for all industrial requirements.

NUCLEAR SYSTEMS | Budd

A DIVISION OF THE BUDD COMPANY, Philadelphia 32

Personals . . .

R. B. McCarthy has been appointed chief engineer of the steel mill division of Surface Combustion Corp., Toledo, Ohio. A member of the company for nine years, Mr. McCarthy's early experience with the corporation was in the erection department working on the operation and construction of all types of steel mill equipment. Until taking over his new assignment, he was assistant chief engineer.

Raymond A. Barry, formerly chief chemist of Electric Auto-Lite Co., Cincinnati, Ohio, was recently appointed a sales engineer for the Cincinnati district by Wagner Brothers, Inc., Detroit.

Gerald Abowitz, recently released from the Corps of Engineers, U. S. Army, is attending Yale University as a General Electric Co. Fellow in metallurgy, studying for his doctorate degree in engineering.

Donald F. Stoneburner is undertaking full-time graduate study at the Carnegie Institute of Technology as a Union Carbide Corp. Fellow, working toward a Ph.D. degree in metallurgical engineering. During this time he will be on a leave-of-absence from the Oak Ridge National Laboratory where he is currently employed as an associate metallurgist.

Richard B. Gordon has resigned as manager, core engineering department, at the Bettis atomic power division of Westinghouse Electric Corp. to accept a position as nuclear specialist in the Atomics International Div., North American Aviation, Inc., Canoga Park, Calif.

J. William Robinson has been named president of the newly organized Leeds & Northrup, Canada, Ltd., Toronto, a wholly owned subsidiary of Leeds & Northrup Co., Philadelphia. The new firm will manufacture and distribute the electronic controls and measuring instruments formerly supplied from the United States. The production manager and assistant secretary for the company is **J. Robert Gowen**. Both Mr. Robinson and Mr. Gowen were formerly concerned with the western operations of Leeds & Northrup which included Canada.

Personals . . .

Edgar W. Engle has been appointed development engineer for Kennametal, Inc., Latrobe, Pa., in connection with the company's current expansion program. Mr. Engle, formerly technical director for the Vascoloy-Ramet Corp., Waukegan, Ill., will be concerned with the development of new products.

F. H. Alviset is currently employed as chief engineer for Atlas Pipe Inc., Houston, Tex.

A. Dean Meyer has been named general manager of the Ajax Electrothermic Corp., Trenton, N.J., to succeed **Guilliam H. Clamer**. Mr. Meyer, who joined the company in 1929, has served the company as a vice-president since 1947 and more recently was named a director. Dr. Clamer had held the position of general manager since the formation of the company in 1920; he will continue to serve as president.

Louis V. Privoznik has accepted a position as supervisor of the manufacturing development laboratory with Westinghouse Electric Corp.'s steam division in Lester, Pa.

E. D. Cowlin has resigned after 33 years of continuous service with the Reliance Div., Eaton Mfg. Co., Massillon, Ohio. Mr. Cowlin became manager of the New York district sales office of Reliance Mfg. Co. in 1924, and after Eaton acquired Reliance was appointed general sales manager and finally general manager of the division. He will be succeeded as general manager by **Chester A. Sellen**. Mr. Sellen had been assistant general manager and chief metallurgist of the division for the past three years.

Carl Ludwig has been made chief engineer of the engineered products division of the Wellman Engineering Co., Cleveland, an affiliate of the McDowell Co., Inc. Mr. Ludwig was added to Wellman Engineering's staff in 1956, and prior to that time was affiliated with the Rolling Mill Div. of Olin Mathieson and the Adamson Div. of Hydropress, Inc.

Matthias P. Rival is now chief plant engineer for the Fafnir Bearing Co., New Britain, Conn.

Personals . . .

Michael Ference, Jr., Ⓜ is currently director of the scientific laboratory, engineering staff, Ford Motor Co., replacing **Dr. A. A. Kucher** Ⓜ who was named vice-president, engineering and research, for the company.

Sherwood W. McGee Ⓜ is now associate metallurgist with the Armour Research Foundation of Illinois Institute of Technology in Chicago, where he has been employed since his graduation from the University of Illinois in 1952.

John L. Cotsworth Ⓜ has been named staff manager, stainless steel, for Chase Brass & Copper Co., Waterbury, Conn. For the past year, Mr. Cotsworth was manager of sales for Northeastern Steel Corp. Bridgeport, Conn., and before that was on the sales staff of Atlas Steels, Ltd., Welland, Ont.

Kelvin Sproule Ⓜ has been transferred to the development and research division of the International Nickel Co., in New York, where he will be concerned with Inco's investigations on the use of atomic energy effects in research. Mr. Sproule had been a consulting metallurgist on the staff of the International Nickel Co. of Canada, Ltd., at Copper Cliff, Ont., and from 1948 to 1955 was superintendent of research for Inco of Canada.

Edwin R. Young Ⓜ has been named to the newly created position of employee counselor in the personnel department of the Norton Co., Worcester, Mass. Mr. Young has served the company for over twenty years in various supervisory positions.

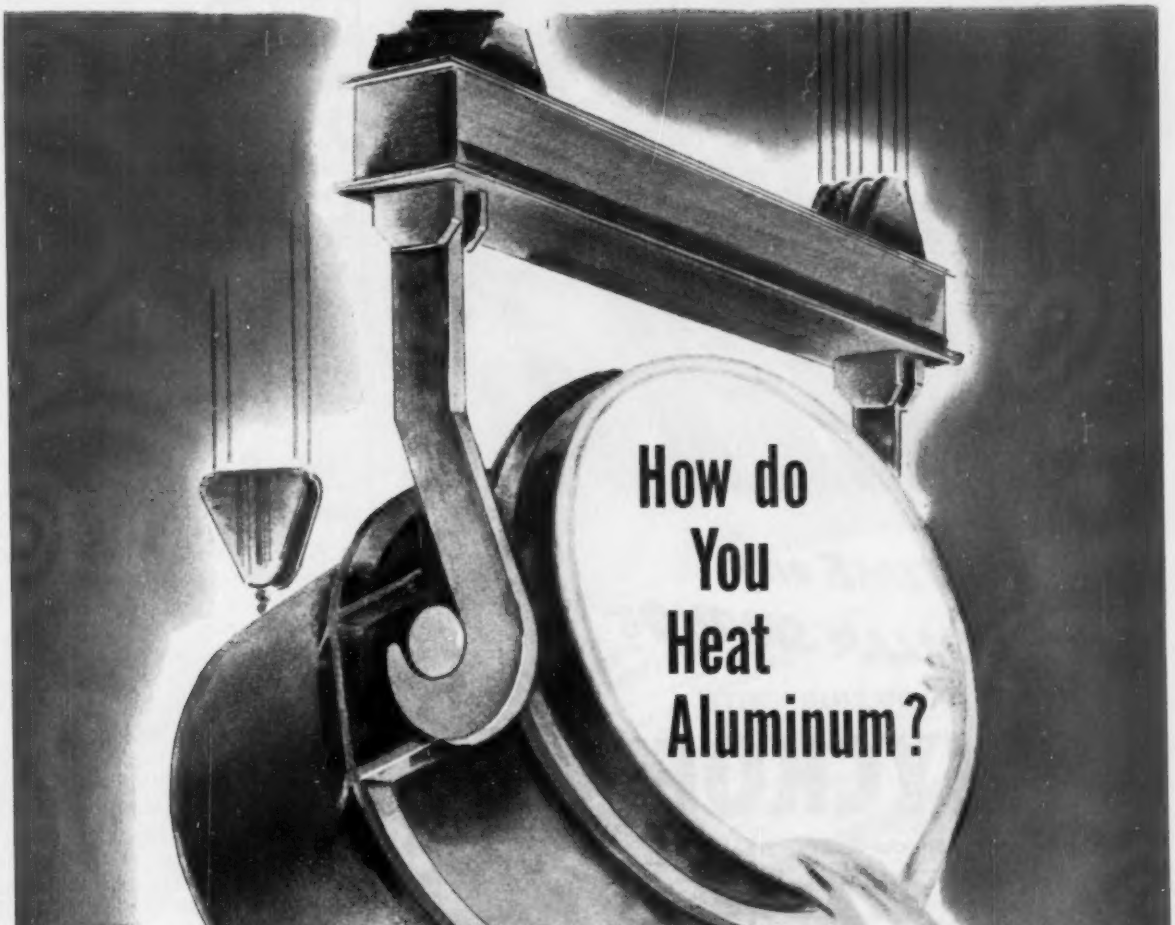
Lee F. Weitzenkorn Ⓜ has been assigned the post of assistant to the works manager of Armco Steel Corp.'s Baltimore, Md., works. Formerly Armco's work metallurgist, Mr. Weitzenkorn will coordinate the steel works' quality control and develop improved processing procedures. At the same time, **John S. White** Ⓜ has been promoted to works metallurgist to succeed Mr. Weitzenkorn. Supervising metallurgist until this promotion, he will now be in charge of the metallurgical department.

Personals . . .

Stanislaus S. Thomas ⊕ recently joined the reactor engineering division of Argonne National Laboratory in Lemont, Ill. Prior to joining the Laboratory, he was an assistant professor of mechanical engineering at the University of Notre Dame.

John Chipman ⊕ has been nominated vice-president of the Metallurgical Society of the American Institute of Mining, Metallurgical, and Petroleum Engineers for 1958. The vice-president automatically assumes the office of president of the society in 1959. Dr. Chipman, a past president of A.S.M., is professor of metallurgy at Massachusetts Institute of Technology, where he has been teaching for 20 years. In addition, **Carleton C. Long** ⊕ director of the research department, St. Joseph Lead Co., Monaca, Pa., **Cyril Stanley Smith** ⊕, director of the Institute for the Study of Metals of the University of Chicago, **James B. Austin** ⊕, vice-president, fundamental research, U.S. Steel Corp., Pittsburgh, **J. S. Smart, Jr.,** ⊕ assistant to the vice-president and director of research, American Smelting & Refining Co., Plainfield, N.J., **Karl L. Fetters** ⊕, assistant to the vice-president in charge of operations, Youngstown Sheet & Tube Co., Youngstown, Ohio, and **Harold B. Emerick** ⊕, director, technical service, Jones & Laughlin Steel Corp., Pittsburgh, have all been nominated to the Metallurgical Society board of directors.

Arthur W. Thornton ⊕ has been nominated by the Metallurgical Society of the American Institute of Mining, Metallurgical, and Petroleum Engineers as A.I.M.E. vice-president for one year. Mr. Thornton is assistant to the vice-president, operations, for National Tube Div. of U.S. Steel Corp., Pittsburgh. Joining the company in 1934, he has held his present position since 1954. **Walter R. Hibbard** ⊕ is the Society's nomination for A.I.M.E. director. Mr. Hibbard, who is manager of alloy studies at the General Electric Research Laboratory, Schenectady, N.Y., is vice-president of the Metallurgical Society and will be its president next year.



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MELT IT...
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PRE-HEAT IT...
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SWEAT IT...
RECLAIM IT...
HOMOGENIZE IT...
HEAT TREAT IT...
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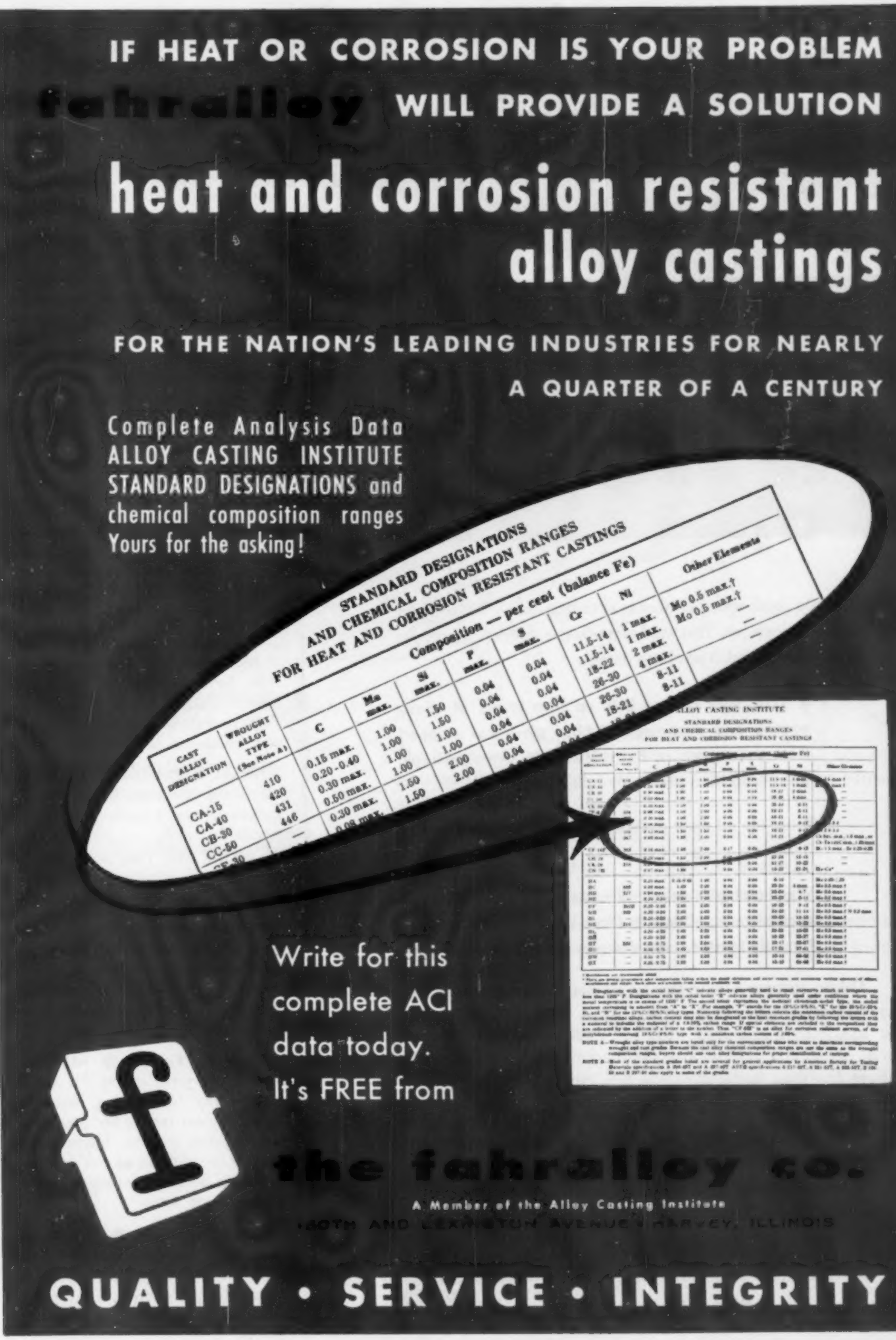
Personals . . .

L. A. Stoyell has assumed new responsibilities as metallurgical engineer in charge of manufacturing for the new fine metals and chemicals division of the product and process department, Electro Metallurgical Corp., Niagara Falls, N. Y. This new division will be responsible for the manufacture and sales of new alloys, pure metals, and other new products. Mr. Stoyell joined Electromet in 1940 and has held a number of metallurgical research and engineering positions prior to his new appointment.

John S. Worth and **Thomas G. Foulkes** have been appointed metallurgical engineers at Bethlehem Steel Co., Bethlehem, Pa.

Wylie J. Childs has been appointed visiting professor on the departmental staff of Rensselaer Polytechnic Institute. Dr. Childs, who has come to the Institute from Lafayette College, will devote his major effort to building up laboratory research and teaching in the general field of melting and solidification of metals. Allegheny Ludlum Steel Corp., Pittsburgh, has made a $5,000 grant to the Institute toward the salary of a professor to lead study and research on the melting and solidification of metals, and Dr. Childs has been selected to receive this grant.

Several members are among those nominated as officers in the three divisions of the Metallurgical Society of A.I.M.E.. **Herbert H. Kellogg**, professor in the School of Mines of Columbia University has been named chairman of the Extractive Metallurgy Div. In the Institute of Metals Div., **Oscar T. Marzke** of the Naval Research Laboratory in Washington, D.C., has been named senior vice-chairman and **Prof. Thomas A. Reed** of the University of Illinois has been nominated vice-chairman. **George A. Roberts**, Vanadium Alloys Steel Co., Latrobe, Pa., and **David Swan**, Electro Metallurgical Co., Niagara Falls, N.Y., have both been named to the executive committee of the division. **Karl L. Fetters** is new chairman of the Iron and Steel Div. and **Michael Tenenbaum**, Inland Steel Co., East Chicago, Inc., is vice-chairman.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Personals . . .

Lester E. Cooney, former district manager of the Chicago-Milwaukee-St. Louis sales territory, has become assistant to the vice-president in charge of sales for the Carpenter Steel Co., Reading, Pa. Mr. Cooney started with Carpenter in 1924, and has served as Chicago district manager for the past 16 years. At the same time, **William J. Stephens** has been transferred from St. Louis branch manager to Chicago branch manager, and **M. R. Gerhart**, sales representative in the Chicago area, has been named to succeed Mr. Stephens in St. Louis. Other appointments include **Martin J. Holleran** who has been named district manager of the northern New Jersey territory and **Donald F. Ross**, now assistant branch manager in the Dayton area.

Ralph J. Pukas has become a member of the staff of the engineering department of Diamond Crystal Salt Co., St. Clair, Mich., where he will act as design engineer.

F. D. Illingworth is currently district manager in charge of the New Jersey and New York State territory for A. Milne & Co., New York, operating from the company's new warehouse in Kenilworth, N. J.

Robert E. Renders has established the Syracuse Metal Testing Laboratory in Syracuse, N. Y. to service foundries and fabricators in the central New York State area by providing chemical analysis, physical testing and a consulting service.

Bernard Trock has expanded his special digest service to include a metallurgical consultant service in Detroit, specializing in material, process and heat treat specifications and service failure analysis.

Frank L. LaQue has been elected vice-president of the American Society for Testing Materials for a two-year term. Mr. LaQue is vice-president of the International Nickel Co. and has served as manager of its development and research division since 1954.

Garrett A. Busch is now an assistant in research and development at the Cleveland Graphite Bronze Corp., Cleveland, working with powder metals.

Personals . . .

E. S. Waldbott has left his position as chief metallurgist and process engineer at Vard, Inc., Pasadena, Calif., to accept a position as senior metallurgist at Convair, a division of General Dynamics Corp., in Pasadena, Calif.

Tom Richardson, after five and one-half years as general engineer with the U.S. Army in Japan, working on joint U.S. Forces procurement (inspection, quality control and production), has moved into the design field at the new Naval Air Station at Cubi Point, Bataan, Philippines. He is now electrical engineer in charge of electrical work, plans and installations at this new air base.

William H. Miller has accepted the position of metallurgical trainee at the Corpus Christie, Tex., plant of the American Smelting & Refining Co.

J. R. Small is now engaged in metal control work for the Stanley Foundries of Huntington Park, Calif., following eight years as supervising metallurgist with the U.S. Naval Ordnance Test Station in China Lake, Calif.

A. H. Greisser has been promoted to superintendent of production for Portland General Electric Co., in charge of operation and maintenance of the company's hydro and steam electric generating plants.

Dean D. Lawthers, formerly engaged in work on refractory metals with Westinghouse Electric Corp.'s research laboratories is now working on refractory metals at Universal Cyclops Steel Corp., Pittsburgh, in the company's pilot plant.

Chester S. Pondo has joined the Custom Tube and Spring Co., Sierre Madre, Calif., as chief metallurgist and vice-president. Before accepting this new position, Mr. Pondo was chief metallurgist and materials engineer for the Wiancko Engineering Co., Pasadena, Calif.

D. F. Sawtelle has joined Exomet, Inc., as a sales engineer. Prior to this new appointment, Mr. Sawtelle was chief metallurgist for the iron and steel foundries of Malleable Iron Fittings Co.

Personals . . .

Richard W. Holmes has become sales manager of the eastern division, north, of E. F. Houghton & Co., with headquarters in Worcester, Mass. Mr. Holmes moves to his new post from Detroit, where he was on the Houghton sales staff. He joined the company in 1950, following metallurgical work for Chrysler Corp., Detroit and J. E. Bullock Corp.

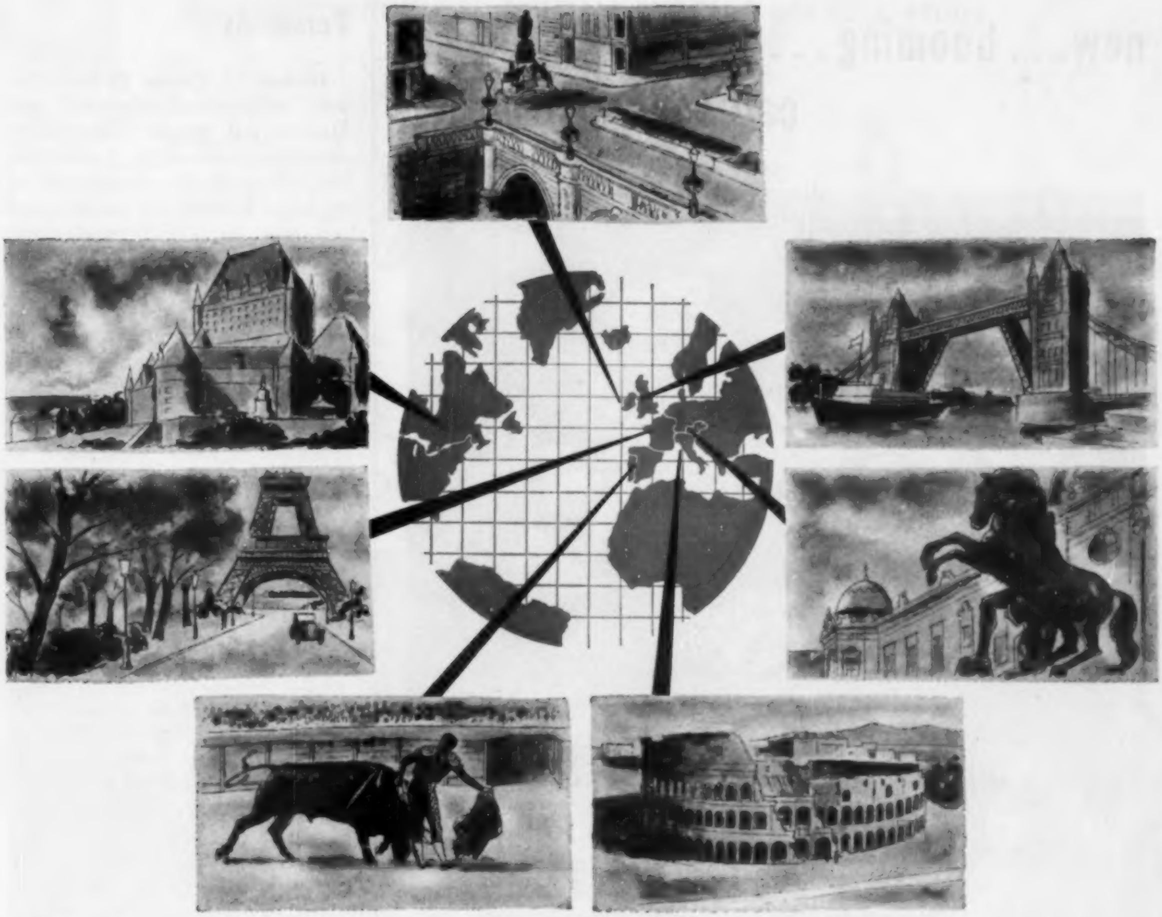
Edward Murway recently was appointed practiceman in the galvanizing department of Inland Steel Co., East Chicago, Ind.

William R. Martin and **Ronald S. Mulhauser** have joined the staff of the metallurgy department of Goodyear Atomic Corp., Portsmouth, Ohio. Both Mr. Martin and Mr. Mulhauser are recent college graduates, the former receiving his degree from the University of Cincinnati, the latter from Carnegie Institute of Technology.

Henry Otto Steinmetz is now engaged in engineering and development work on nuclear materials at the Bettis plant of the atomic power research laboratory of Westinghouse Electric Corp., Pittsburgh.

C. M. Schwitter, formerly supervisor of Far Eastern and Latin American technical developments, has been chosen to head the market research activities of the International Nickel Co., Inc., New York. Mr. Schwitter will be assisted by **George Hoobler**, formerly a member of the steel section of the company's nickel sales department. Joining Inco in 1930 as a research metallurgist, Mr. Schwitter was placed in charge of Far Eastern technical developments for the company and in 1956 his duties were expanded to embrace Latin American technical development. Mr. Hoobler joined the company in 1947, at the Bayonne, N.J., works, later serving in the Pittburgh technical field section and more recently in New York as a member of the nickel sales department.

R. H. Robinson has been transferred from the Detroit office of the General Alloys Co. to the Buffalo office of the company as sales manager of the western New York area.



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Personals . . .

Herbert M. Frazier heads the new International Chemical and Metallurgical Supply Corp. offices recently opened in Ft. Lauderdale, Fla., to supply the requirements of the metal finishing and metallurgical industries in Florida and Latin America. Mr. Frazier is president of the company while **Wendell P. Barrows**, formerly affiliated with the National Bureau of Standards and the Naval Gun Factory, has been named secretary.

Donald A. Toland has been appointed a junior technologist in the vitreous enameling section of U. S. Steel Corp.'s Applied Research Laboratory, Monroeville, Pa.

Herbert A. Ball was recently named quality control manager of the Nuclear Fuel Div. of Olin Mathieson Chemical Corp., New Haven, Conn.

K. P. Campbell, works metallurgist for the Sheffield Div. of Armco Steel Corp. in Houston, Tex., has been promoted to general superintendent of operations, in charge of all phases of production. His former position will be filled by **G. W. Brooks**, process metallurgist. At the same time, several appointments were announced at the Kansas City Works of the Sheffield Div. **J. N. Goldsmith** was named assistant to the works manager and **J. A. Walker** was promoted to supervising metallurgist.

Lester A. Shea has been appointed eastern division manager of the Lindberg Industrial Corp., Chicago, with headquarters in Fair Lawn, N.J. Mr. Shea has been affiliated with the Lindberg organization for over 20 years, joining Lindberg Engineering Co. in 1937 and transferring to Lindberg Industrial Corp. in 1954.

V. K. Entrekin has left his position with Applied Research Laboratories in Miami, Fla. to take a post in the manufacturing and development division of Convair, a division of General Dynamics Corp., San Diego, Calif.

Robert H. Miller is currently superintendent of nonferrous foundry for the Universal Foundry Co., Oshkosh, Wis.

Digests of Convention Papers

Influence of Nickel on Corrosion of Chromium Steels

Digest of "Influence of Nickel on Intergranular Corrosion of 18% Chromium Steels", by J. R. Upp, F. H. Beck and M. G. Fontana, Preprint No. 51, 1957.

TYPES 304 and 430 steels can be made relatively immune to intergranular attack or made susceptible (sensitized) through selected heat treatments. Of interest is the fact that one heat treatment makes a steel immune and the other makes it susceptible. The question arises – at which nickel content does the switch occur?

One theory which explains the intergranular attack on Type 304 heat treated between 900 and 1400° F. is based on chromium impoverishment – lowering the chromium content adjacent to $Cr_{23}C_6$ precipitates results in less corrosion resistance in the adjacent areas. This may be avoided by treating at 2000° F. and water quenching to prevent carbide precipitation or by adding cobalt or titanium – both strong carbide formers – to the original melt to reduce the available carbon.

With Type 430 steel intergranular corrosion occurs in samples which have been cooled rapidly from 1700° F., but this attack may be prevented by short-time heating at 1450° F. Interesting facts about this attack are:

1. Martensite corrodes more than ferrite.

2. A precipitate of iron carbide can cause corrosion, although heat treating can cause the carbide to revert to a $Cr_{23}C_6$ which resists corrosion.

3. Titanium will not prevent intergranular corrosion by carbon removal, with attack still occurring when the carbon is only 0.005%.

4. Attack may be in stressed regions in the grain boundary caused by carbides or nitrides formed on quenching, but this stressed region may be removed by treating at 1450° F.

To investigate intergranular attack, 12 alloys of 18% chromium stainless steels were prepared with nickel contents from 0 to 8.3%. After melting, the alloys were cast into round bars and rolled at 2000° F. into strips which were air cooled. These specimens were given various heat treatments and tested for corrosion resistance in a 240-hr. Huey corrosion test using boiling 65% HNO_3. Data are reported in mils penetration per year. No photomicrographs are given. Metallographic studies on each specimen showed evidence of intergranular corrosion. The only effective heat treatments found were water quenching and furnace cooling from 1400 or from 2000° F. These heat treatments were either sensitizing or immunizing depending on the steel in question.

A sharp change in corrosion rates was found between 2.5 and 3.0% Ni content – specimens furnace cooled from 2000° F. showed extreme attack. In the low-nickel alloys the corrosion mechanism is one that would be exhibited by ferritic steels, whereas for nickel contents above 3% the austenitic-type mechanism dominates. This was verified from microstructures of the various alloys. The low-nickel alloys at 2000° F. showed a structure predominantly ferritic with 10 to 40% martensite, while at 1400° F. the structure consisted of masses of dark carbide in an all-ferritic matrix. The Fe-Cr system should not have martensite present, but with carbon the two-phase region of the gamma loop is moved to the right. Up to 5% Ni, alloys at 2000° F. showed more martensite and less ferrite, while at 1400° F. the structures were tempered martensite with ferrite stringers. At 2000° F. the 5 to 7% Ni alloys were just in the austenite field, and at 1400° F. the specimen exhibited severe grain-boundary corrosion.

One unusual fact noted was that all specimens water quenched from 1400° F. showed no intergranular attack, although the structures were different. Prior heat treatments were found to have little influence on the results of the heat treatments given to the alloys before testing. Comparison tests between commercial and laboratory Type 304 and 430 steels were good, with the commercial alloys being attacked slightly more.

The authors believe that 18% Cr steels containing from 0 to 2.5% Ni can be properly heat treated – where intergranular corrosion is concerned – as ferritic steels, and those containing more than 3% Ni fall into the category of austenitic steels and should be heat treated accordingly.

D. L. McELROY

Effect of Manganese on Curie Temperature of Cementite

Digest of "Effect of Manganese on the Curie Point of Cementite", by Earl C. Roberts, Preprint No. 11, 1957.

A NUMBER of alloying elements – particularly carbide formers – are known to replace iron in the cementite lattice. The alloying of cementite with manganese in steels and cast irons has been studied by several investigators using techniques of electrolytic extraction and chemical analysis. In the present work, this approach has been combined with determination of the Curie temperature of the cementite in a systematic examination of the change in manganese content of the cementite as a function of the manganese and carbon percentages in the steel.

Three series of steels of different carbon contents were used. In each series the manganese level was relatively constant (roughly, 0.25, 0.50, and 0.90%) and all were especially

Curie Temperature . . .

prepared to have a minimum residual alloy content. A high-purity iron-carbon alloy of approximately 1.00% carbon was included in the study to establish a reference Curie temperature for manganese-free cementite. To avoid difficulty with variations in Curie temperature with very fine cementite or as a result of cold working, all specimens were annealed in vacuum for 100 hr. at 1200° F. after machining and cleaning. After magnetic measurements were made to determine the cementite Curie temperature (averaging results obtained by slowly heating and cooling to above the transition temperature), the carbides were extracted electrolytically from the specimen and analyzed for iron and manganese.

The results show a linear decrease in the Curie temperature of the cementite with increase in the manganese content of the carbide. The relationship can be expressed by the equation:

$$\text{Curie temperature } (^{\circ}\text{F.}) = 406 - 39.3\ (\%\ \text{Mn in cementite})$$

This simplified expression gives an approximate calculation if either of the two variables is known.

Of some practical importance is the relationship between the percentages of manganese in the steel and manganese in the cementite. This has previously been thought to be a straight line, but the present investigation indicates a curvilinear relationship. A very marked dependence on the percent carbon in the steel was also observed. Thus, the relationship between the manganese content of cementite and the manganese content of the steel can be expressed as a parabolic equation in which the carbon content of the steel must be considered. The empirical equation derived for this relationship was tested against the experimental data with an overall error of only about 6% for the range of conditions studied.

The author points out that in the two specimens for which the empirical equation failed, the silicon content either was low or was undetermined. This is given as indication of the importance of silicon on the distribution of manganese between carbide and ferrite in annealed steels. G. H. ENZIAN

Limits of Solubility of Carbon in Thorium

Digest of "Solubility of Carbon in Thorium", by Robert Mickelson and David Peterson, ⊕ Preprint No. 7, 1957.

PRIOR STUDIES of thorium alloys have indicated that carbon is the most effective addition for increasing the hardness and strength without seriously reducing ductility. The stable carbide phase in equilibrium with thorium at room temperature is thorium monocarbide, and it is completely soluble in the liquid and solid states at high temperatures. At intermediate temperatures, the limits of carbon solubility have been studied only briefly in early work by Saller, who found discrepancies between results obtained by the X-ray and metallographic methods. The present study was undertaken to provide additional fundamental data.

Carbon solubility was determined by X-ray measurements of the lattice parameter of slowly cooled and quenched specimens of thorium-carbon alloys. A North American Phillips back-reflection camera (12 cm. diameter) was used. The results of the X-ray tests were verified by metallographic examination and hardness tests.

The thorium-carbon alloys were prepared by arc melting low-carbon, bomb-reduced thorium sponge with high-purity graphite in a purified helium atmosphere. Each sample was turned and melted three times to insure homogeneity. Carbon contents of the 17 alloys analyzed between 0.025 and 1.23% by weight. The average nitrogen content was 0.032%, and values of individual alloys were generally within 50% of the average value. Spectrographic analyses of the sponge and several of the alloys showed only small amounts of the several metallic impurities normally found in thorium metal. Thorium oxide, not determined analytically, was estimated metallographically to be present in amounts ranging between 1 and 2%.

Specimens containing less than 0.1% C were prepared by hot rolling into 1/16-in. thick sheet. The more brittle, higher-carbon specimens could not be rolled, and were cut into blocks 1/16 in. thick and 1/4 in. wide.

The room-temperature solubility

Carbon in Thorium . . .

limit was determined on specimens held at 900° C. (1650° F.) for 6 hr. and cooled to room temperature over a 5-day period. During heat treatment, specimens were contained in quartz tubes evacuated to less than 0.02μ. Solubility limits at higher temperatures were determined on specimens which were heated for ½ hr. or more in a vacuum of 0.4μ or less. Specimens were quenched by allowing them to fall directly into a bath of Wood's metal at 80 to 100° C. (175 to 212° F.).

Prior to X-ray examination, specimens were vigorously pickled in dilute nitric-hydrofluoric acid to remove surface metal possibly contaminated during heat treatment. Most of the X-ray photographs showed sharply defined lines of thorium oxide, and these lines were used as internal standards to eliminate systematic errors in determination of the lattice constants of the metal. Samples containing in excess of about 0.5% C were very coarse-grained and gave spotty patterns so that a large random error was present with such specimens.

The lattice parameter of the different specimens increased with carbon content and leveled off at values taken to be the limit of carbon solubility at the different temperatures. The data indicate that thorium will dissolve 0.3% C at room temperature, 0.43% carbon at 800° C. (1470° F.), 0.57% carbon at 1018° C. (1680° F.), and 0.91% carbon at 1215° C. (2220° F.). These results were confirmed by metallographic examination. Thorium carbide was identified as small square particles, easily differentiated from the larger and darker thorium oxide particles.

An anomalous effect was observed in samples containing less than 0.35% C in that the lattice constant and hardness of quenched specimens were greater than those of slowly cooled specimens. This behavior was attributed to the presence of nitrogen as an impurity in amounts greater than the solid solubility at room temperature. Additional nitride retained in solid solution by quenching from elevated temperatures probably caused the increased lattice constants and greater hardnesses that were observed.

R. E. Adams

Effects of Cycling on Rate of Growth of Rolled Uranium

Digest of "Effects of Cycling Variables Upon Growth Rate of 300° C. Rolled Uranium", by R. M. Mayfield, ASM Preprint No. 37, 1957.

Because of its high degree of preferred orientation when in rod form, uranium can undergo permanent growth when subjected to thermal cycling. The amount of growth is determined by the texture of the material and the cycling conditions. An accurate knowledge of the effects of variations in the latter is required before an adequate theory of the effect can be formulated. The present work represents a comprehensive study of the effect of heating and cooling rates, temperature limits and other cycling conditions on the rate of growth.

The majority of the work was carried out in a vertical tube cycling apparatus having two chambers held at different temperatures. Specimens of 99.9 + uranium, rolled at 300° C. (570° F.) and annealed at 600° C. (1110° F.), were transferred from one furnace tube to the other by raising in a tube filled with NaK extending between the two.

The growth rate for different conditions was evaluated by comparing the growth coefficient G_t. This coefficient is the true extension per cycle per unit length and is compared to the "instantaneous" length rather than the original length. The growth rate coefficient used was generally that after 100 cycles. The growth rate approached very low values when the upper temperature was 350° C. (660° F.) and below, so that most of the work was confined to temperatures above 350° C. (660° F.). The maximum growth rate occurred with slow heating and fast cooling and with time at temperature of at least 30 min. Reversal of these conditions led to the minimum amount of growth. None of the conditions studied led to zero growth even when very slow rates of heating and cooling were used. This fact tends to discount any theory relying on thermal gradients as a cause of growth.

With increasing upper temperature of the cycle above 350° C.

(660° F.), the growth rate increases sharply. Likewise, a greater temperature range also means greater growth rates. It should be noted, however, that other workers have observed growth when the temperature range was ± 2° C. There appears to remain some conflict over the exact temperature dependence of the growth rate. This difficulty is not readily resolved since the process is not isothermal and it is not clear at what stage in the cycle the growth takes place. It is doubtful that the activation energies calculated from the present data refer to any single process. Any model for the growth mechanism must, however, account for the observed effects of the cycling variables.

RAY W. GUARD

Uranium-Titanium Alloys for Reactors

Digest of "Some Properties of Uranium-Low Titanium Alloys", by Daniel J. Murphy, Preprint No. 40, 1957.

EXTENSIVE USE of natural and enriched uranium in solid form is currently anticipated in several atomic reactors. Many difficulties are encountered, especially in water-cooled and moderated reactors, because of the corrosiveness of water on uranium.

Earlier work in uranium alloys suggested the possibility that by the addition of small amounts of titanium, a product with greater strength and corrosion resistance might be obtained.

Five cast alloys were prepared, ranging from 0.09 to 1.40% Ti by weight. These were subsequently evaluated for tensile, yield, impact and corrosion resistance in a variety of heat treated conditions. In general, increasing titanium contents increased the tensile and yield strengths as well as hardness, while elongation and impact values decreased. The same trend was established on all of the heat treated specimens, with certain exceptions: Elongation increased and impact strength decreased for all compositions heat treated, except those that were water quenched from 725° C. (1335° F.). In these samples, a distinct plateau for all compositions up to 1% Ti was exhibited, with values

U-Ti Alloys . . .

in the range of 20% elongation and 20 ft-lb. impact.

Increasing titanium content also increased resistance to water corrosion. As little as 0.1% Ti increased corrosion resistance ten-fold, and quenching from 800° C. (1470° F.) brought further improvement.

When a 3% Ti alloy was aged by holding 1 hr. at 500° C. (930° F.) hardness increased up to Vickers 600. Precipitation of U_2Ti is suggested as the mechanism.

The author concludes that beneficial mechanical effects result from additions of titanium in the range of 0.1 to 1.5%, that properties obtained depend strongly upon the thermal history and heat treatment, and that there is a finite possibility of achieving these beneficial results in massive pieces by the addition of third elements which would decrease transformation rates in the base metal. Comparative data, curves and photomicrographs are included in the presentation.

J. L. Wyatt

Hydride Precipitation in Alpha Titanium

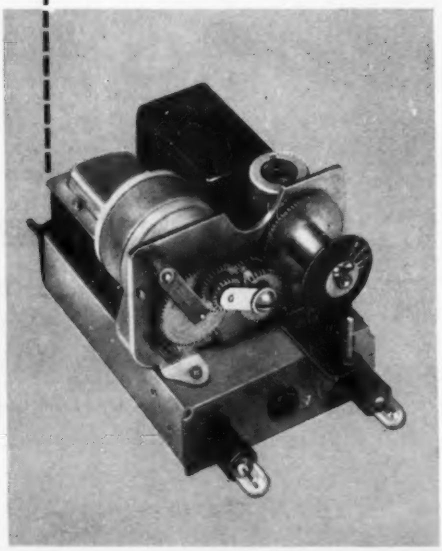
Digest of "The Mode of Hydride Precipitation in Alpha Titanium and Alpha Titanium Alloys", by Tien-Shih Liu and Morris A. Steinberg, Ⓢ Preprint No. 34, 1957.

The detrimental effects of hydrogen upon the mechanical properties of titanium have been common knowledge for some time, and considerable efforts have been spent to elucidate the mechanisms.

Anticipating that knowledge of the mode of hydride precipitation will provide a sounder basis for understanding the hydrogen embrittlement itself, Liu and Steinberg studied the hydride precipitation in alpha titanium and several alpha titanium alloys.

Samples were hydrogenated either in a modified Sivert's adsorption apparatus or in a continuous flow of purified hydrogen. Large hydride particles were formed if hydrogenation at 662 to 752° F. was followed by furnace cooling in hydrogen.

(*Continued on p.* 156)



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Hydrogen in Titanium . . .

Because of the scattering powers of hydrogen and titanium, diffraction methods could not be used for determination of hydride orientation; instead, optical and and metallographic methods were employed, using the two-surface method.

The shape of the precipitated hydride particles is basically the same in both the pure titanium and in the alloys, namely, thin needles. The following habit planes for precipitation were found:

Ti and Ti-2% V (1010) (1011)
Ti-10% Zr (1011) (1122)
Ti-3% Ta (1011) (1121) (1122)
Ti-3% Al (1011) (1121) (1012)

The following crystallographic relationships were postulated:

(1010)α Ti (101) TiH f.c.t.
[1210]α Ti [011] TiH f.c.t.
and
(1011)α Ti (101) TiH b.c.t.
[1210]α Ti [100] TiH b.c.t.

Two of the habit planes fall on two of the three possible slip planes for titanium at room temperature. The authors suggest that this could conceivably lead to a shortened nucleation period for the slip process. A shortening of this type does not affect the behavior in static tests, but could be noticeable in tests such as impact. K. M. CARLSEN

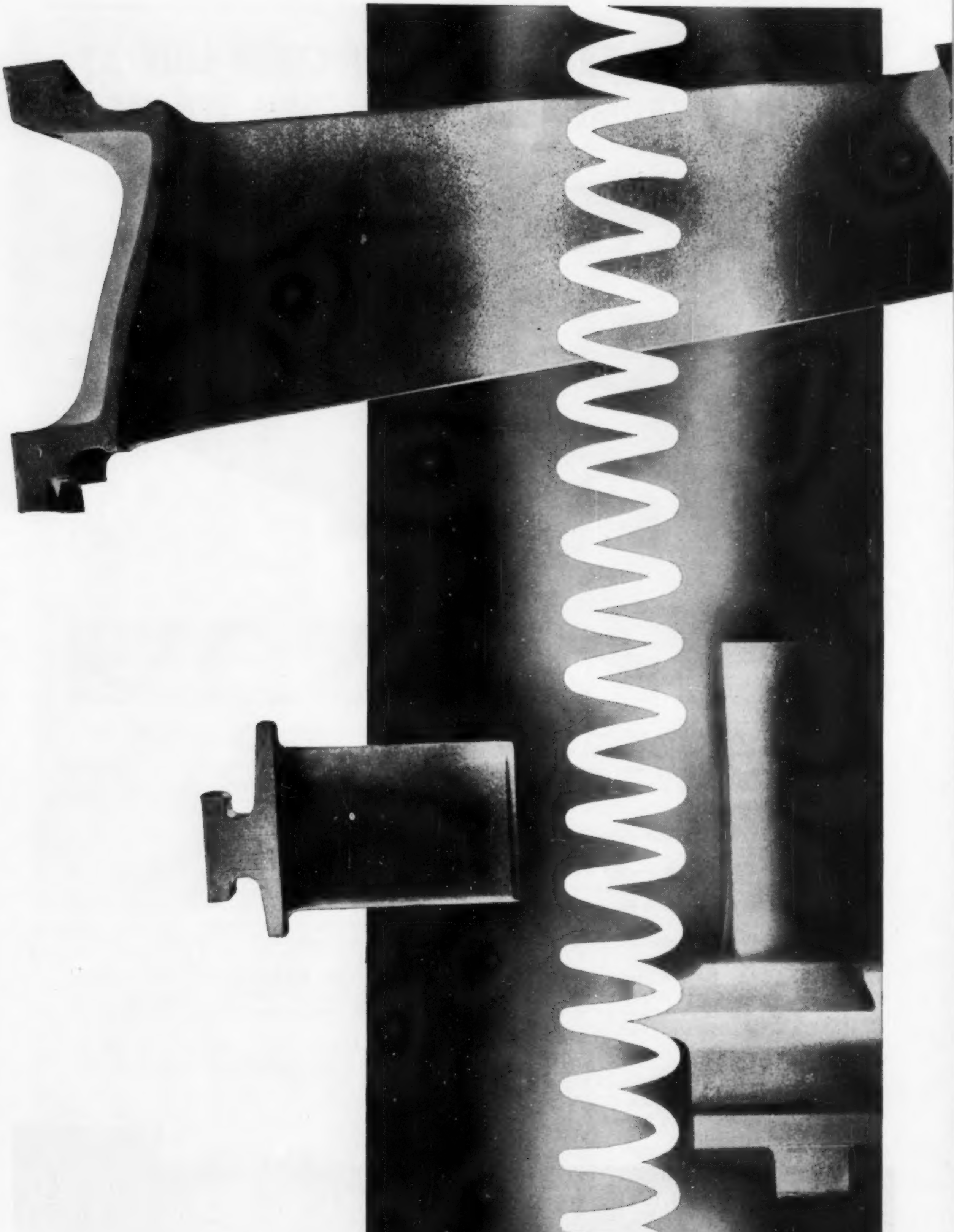
Cause of Brittle Failure of Mild Steels

Digest of "The Initiation of Brittle Fracture in Mild Steel", by J. A. Hendrickson, D. S. Wood and D. S. Clark, ⊕ Preprint No. 28, 1957.

THE RESULTS presented in this paper add to our knowledge of the cause of brittle failure of mild steels. Notched tensile specimens of annealed mild steel were subjected to constant rates of loading at different temperatures. The interrelation between temperature, loading rate and stress state beneath a notch, which governs the initiation of brittle fracture, was quantitatively determined.

Since a notched tensile specimen exhibits both elastic and plastic deformation prior to brittle fracture, an elastic-plastic stress analysis appro-

(*Continued on p.* 160)



Brittle Failure . . .

priate for the experimental results obtained in this investigation was developed. The necessary assumptions were:

1. The material was assumed to be homogeneous and isotropic in both the elastic and plastic regions.

2. Hook's law was assumed to apply at any point in the elastic region.

3. The material was assumed to be free of strain hardening.

4. Plastic deformation will occur when the maximum shear stress reaches a critical value.

5. The direction of the maximum shear stress was assumed always to lie in a constant fixed plane.

6. The displacements of the free (notch) surface will be small enough so the shape of the notch contour during plastic deformation need not be taken into account.

A 0.17% carbon steel in the form of $\frac{5}{8}$-in. diameter bars was annealed and notched in a curvature which was a hyperboloid of revolution. The dimensions of the notches were determined by an optical comparator. The load was applied at desired constant rates, and determined as a function of time by a dynamometer and oscillograph record. Specimens were tested at temperatures of -25, -110 and -200° F. The position of the elastic-plastic boundary was determined experimentally for several specimens at -110 and -200° F. by micro-hardness tests in the vicinity of the notch.

The results showed that the position of the elastic-plastic boundary at the base of the notch determined experimentally was in agreement with the position predicted by the stress analysis.

The true tensile stress at the position and at the instant of brittle fracture was determined from the experimental results by stress analysis. Brittle fracture was initiated in the steel studied at 210,000 psi. This value was independent of stress rate and temperature. Brittle fracture in the notched specimens depended on notch acuity, stress rate and temperature. The influence of stress rate and temperature on the initiation of brittle failure was found to be associated entirely with the dependence of the yield stress on temperature and stress rate.

D. J. Carney

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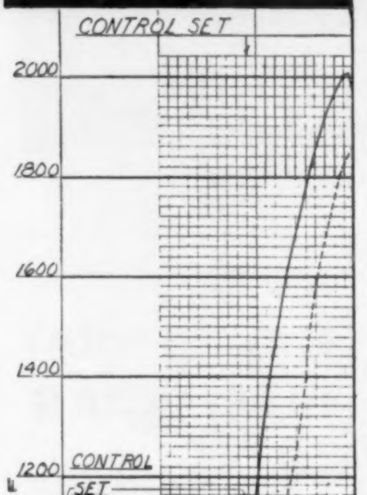

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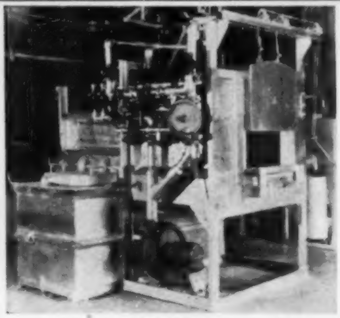

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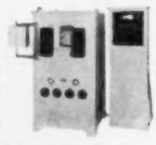

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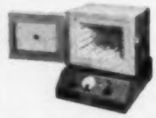

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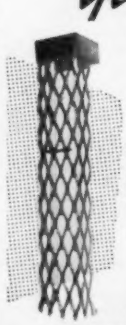

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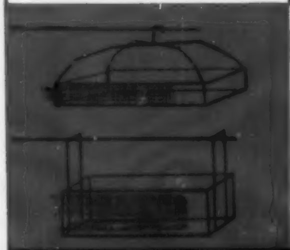

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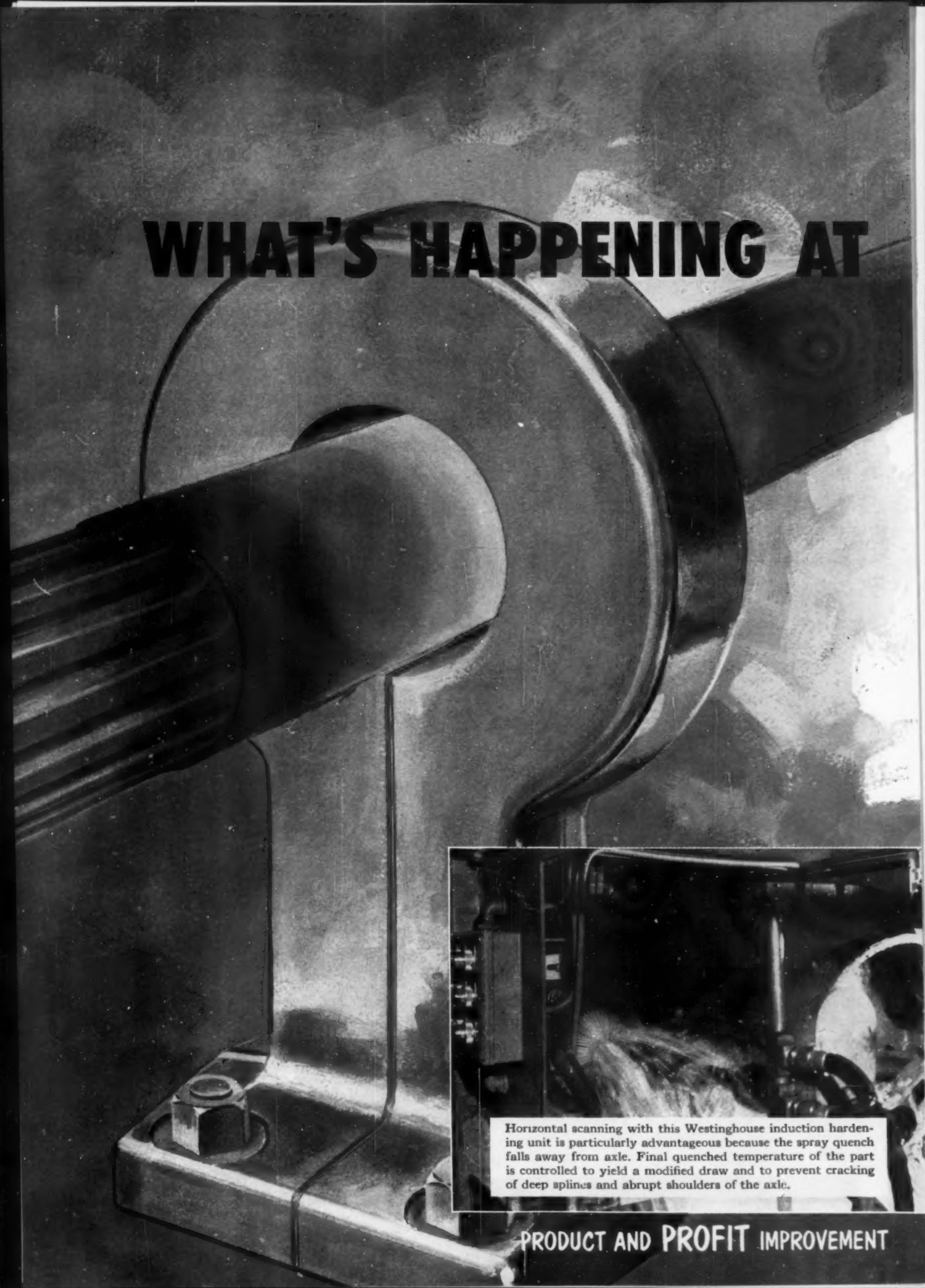

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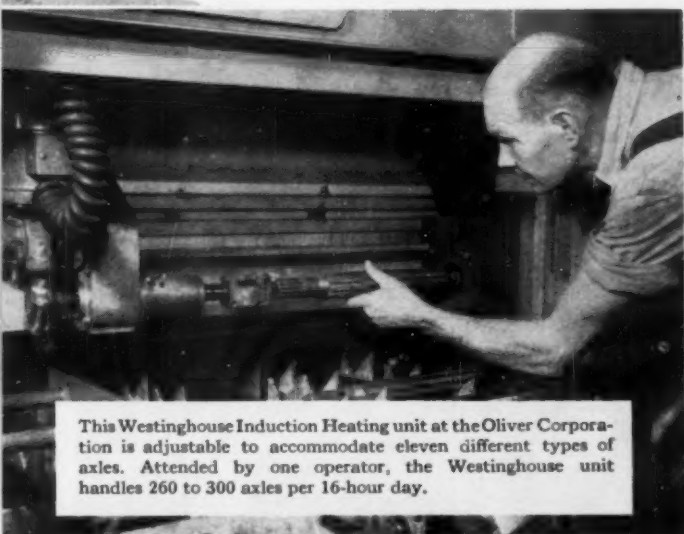

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Role of Carbon in Temper Embrittlement

Digest of "A Study of the Role of Carbon in Temper Embrittlement", by E. B. Mikus and C. A. Siebert, ⊕ Preprint No. 39, 1957.

THE PHENOMENON of temper embrittlement was investigated by the authors by electron microscopy and autoradiography using carbon-14. The problem was to determine if microstructural changes which occur during embrittling heat treatment could be assignable causes of brittle behavior. The material chosen for the work was S.A.E. 3140 steel of A.S.T.M. grain size No. 8 and analyzing 0.39% C, 0.78 Mn, 0.28 Si, 0.010 P, 0.019 S, 0.61 Cr, 1.26 Ni and 0.04 Mo.

Impact bars were investigated by electron microscopy. Tough bars were obtained by tempering for 1 hr. at 1250° F. in a salt bath after quenching. The embrittled condition was obtained by an additional treatment of the impact bars for 500 hr. at 850° F. in a vertical muffle furnace. The impact transition temperature was −165° F. for the tempered bars and +19° F. for the bars given the embrittling treatment.

Specimens used in autoradiographic studies were decarburized in moist hydrogen and then recarburized with specific amounts of carbon. This was done by pack carburizing with charcoal and $BaCO_3$ containing some carbon-14. These samples were then quenched, tempered and embrittled while sealed in an evacuated Vycor tube. A series was embrittled for 100 to 500 hr. at 850° F.

A survey of the literature on the mechanism of temper embrittlement indicated that current theories regard segregation or precipitation effects as probable causes. The electron metallographic investigation was made to determine if carbide morphology is a significant factor in the problem. The autoradiographic work was designed to determine the extent to which carbon segregation could be responsible for temper brittleness. Carbide precipitation effects were also investigated.

Samples for electron metallographic investigation were polished electrolytically in 20% perchloric acid and then etched with etherial picric

Temper Brittleness . . .

acid. Collodion was the replica material, palladium-shadowed. Electron micrographs were reproduced at 10,000 ×.

Radiographic specimens were polished mechanically and etched with etherial picric acid. Autoradiographs, exposed from 1 to 12 days, were examined at magnifications up to 1000 ×. Various etching and exposure times and specific activity levels were used to obtain the most favorable conditions for observing carbon segregation.

The authors report the following:

1. No continuous film of any kind was observed in the prior austenite grain boundaries of a temper embrittled structure developed in S.A.E. 3140 steel samples.

2. Although carbides were observed in the prior austenite grain boundaries of an embrittled structure, it is unlikely that these have any effect on temper embrittlement, since carbides were also found in similar positions in tough samples.

3. Prior austenite grain boundaries revealed by the etchant were grooves between the grains which increased in depth both with etching time and degree of embittlement. They were not a staining effect of the etchant.

4. Neither autoradiographic nor electron metallographic studies revealed that carbon atoms or carbides had segregated to the prior austenite grain boundaries of embrittled structures.

Because of their experience the authors propose that temper embrittlement is brought about by a strain developed across prior austenite grain boundaries at the embrittling temperature and that it is a result of contraction of the ferrite lattice when dissolved alloying elements are removed from solution in the ferrite by reaction with the existing minor carbide phase.

S. T. Ross

Transformation Structures in Hypo-Eutectoid Alloy Steels

Digest of "Transformation Structures in Hypo-Eutectoid Alloy Steels", by W. C. Hagel and M. N. Ruoff, ⊕ Preprint No. 25, 1957.

THE USEFUL mechanical properties of tonnage and specialty steels depend basically upon the structures resulting from commercially practicable cooling rates.

Fundamental principles and experimental facts have been presented to account for the formation of pearlite but further study is needed to explain the formation of pro-eutectoid ferrite and bainite. It is felt that any proposed mechanism should await a better understanding of morphology-controlling factors such as diffusion, interfacial energy, strain energy and nucleation site. Evidence for some of these factors is obtainable with the electron microscope.

Prior investigators have directed their attention to the simple isothermal reactions, and assume correlation with cooling behavior based on the requirement that high and low-temperature transformations are either completely additive or completely independent. However, if the rate of transformation at any temperature depends upon the amount of transformation which has taken place at some higher tem-


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Cooling Behavior . . .

perature, isothermal transformation curves are inadequate for describing cooling behavior.

Both isothermal and cooling transformation curves were determined for five hypo-eutectoid deep hardening steels, and specimens produced under controlled conditions were given a thorough optical and electron microscopic examination to determine the structural details that are required for mechanistic interpretations.

At high temperatures, the dominating morphology-controlling factors are diffusion and interfacial energy; at low temperatures, strain energy and nucleation site dominate; and at any intermediate temperature all of these factors may be present, and the observed structure depends on their relative influence.

A number of conclusions are drawn from this extensive experimental investigation based on examination by optical and electron microscope of a great number of samples resulting from the isothermal and cooling transformation heat treatments performed.

H. J. Elmendorf

Study of Stresses in Cermets

Digest of "Temperature Stresses in the Two-Phase Alloy, WC-Co", by J. Gurland, ⊕ Preprint No. 3, 1957.

Alloys of two phases contain stresses which are caused by the difference of coefficients of thermal expansion and elastic properties of the constituents. If, for instance, the microstructure consists of particles of one phase dispersed in a matrix of another phase, stresses appear in both the matrix and the dispersions during the cooling to room temperature from the stress-free state at higher temperature. It is clear that these locked-in stresses must be of major importance in the consideration of the strength of compacts. It is for this reason that their study is of practical significance.

The author presents theoretical and experimental evidence of the magnitude of such microstresses

(*Continued on p.* 182)

XXIII

This is the twenty-third of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

Annealing: Its Uses with Alloy Steels

Broadly speaking, the primary purpose of annealing is to soften steel and make it more workable. Annealing, as applied to alloy steels, may be defined as a process that heats above, and furnace-cools through, the critical range at a controlled, specified rate of speed; or that heats to a point within, and furnace-cools to a point below, the critical range. In either case, the choice depends upon the structure and maximum hardness desired.

The first method produces a lamellar pearlitic structure, while the second creates a spheroidized condition. These will be discussed separately in the following paragraphs:

(1) *Lamellar pearlitic structure.* It should be mentioned at once that this structure can be obtained both as described above and by a modified method known as isothermal annealing. In the isothermal process, the steel is heated above the critical temperature (austenitized), then transformed at a predetermined temperature, which depends upon the analysis. This operation requires two furnaces or salt baths —one for austenitizing, one for transformation.

Lamellar pearlitic structures are generally associated with machinability in carbon ranges from 0.20 to 0.60 pct, provided the hardness does not exceed the optimum maximum Brinell numeral. This is especially true where critical tooling is involved. It is a very versatile structure, as it gives best results in such operations as broaching, tapping, threading, deep drilling, boring, milling, and tooling as applied on single- and multiple-spindle bar automatic machines.

(2) *Spheroidized structure.* There are two general fields of use for this type of structure when alloy steels are employed. In the low and medium carbon ranges, spheroidization is necessary for cold-shaping operations, such as heading, extruding, drawing. In the higher carbon ranges (over 0.60 pct), it is mandatory where machining is involved, because it tends to lower the hardness of the steel.

As noted elsewhere in this discussion, both lamellar pearlitic and spheroidized structures can be created through annealing. If you care for more details about these and other uses of annealing, and the results to be expected, by all means consult with our technical staff. Bethlehem metallurgists will gladly help you work out any problems. And when you are ready for new supplies of alloy steels, Bethlehem can offer the full range of AISI standard grades, as well as special-analysis steels and all carbon grades.

If you would like reprints of this series of advertisements from No. I through No. XX, please write to us, addressing your request to Publications Department, Bethlehem Steel Company, Bethlehem, Pa. The first 20 subjects in the series are now available in a handy 36-page booklet, and we shall be glad to send you a free copy.

BETHLEHEM STEEL COMPANY
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On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. *Export Distributor:* Bethlehem Steel Export Corporation

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BETHLEHEM STEEL

Stresses in Cermets . . .

(tesselated stresses) in terms of a series of tungsten carbide dispersions in a cobalt-rich solid solution as a binder. The physical constants are particularly well suited for such a study. The coefficient of thermal expansion differs greatly between 100% tungsten carbide (5.4×10^{-6} in. per in. per °C.) and 100% cobalt (12.3×15^{-6} in. per in. per °C.) while Young's Modulus differs in the opposite direction, namely 102×10^6 psi. for 100% WC to 30×10^6 psi. for 100% Co.

It is shown experimentally that the stresses on the WC phase vary from compression, when the phase is completely surrounded by the cobalt matrix (say 35% by volume), to tension when the cobalt fills only the interstices between closely pressed WC particles. In the former case, the cobalt with its higher thermal contraction shrinks about the WC particles during the cooling operation from the sintering temperature, 1400° C. (2550° F.), and thus induces compression in the particles. In the latter case the cobalt, caught in the spaces between WC grains, tends to shrink away from the interface and thus induces tension on the WC particles.

The classical solution of the theory of elasticity applies to the case where one round homogeneous particle is enclosed in an infinite homogeneous matrix. With this as a base the author proceeds to X-ray techniques in order to measure stresses in a series of WC-Co compacts ranging from 5 to 37% cobalt by volume. The (211) diffraction line of the tungsten carbide was found suitable as to strength and sharpness. Both recording X-ray spectrometer and back-reflection camera techniques were employed with a resulting precision of interplanar spacings of within 0.0001 Angstrom unit.

In another series of experiments the grain size of tungsten carbide was varied and the resultant effect with respect to the induced stresses was studied. It was shown that the lattice spacing decreases with increasing grain size (for a compact with 10% cobalt by volume) indicating a reduction in tensile stresses. At higher cobalt contents, where the WC particles are under compression, this effect is much less marked.

The X-ray results represent a statistical average of the strains in the carbide lattice and do not provide a more detailed insight into the state of stress near the interfaces which is complicated by geometry and anisotropy of the WC grains. The results do, however, show good agreement with the theoretical prediction and add another piece of information to the study of stresses in cermets.

F. Forscher

Dislocation Theories Applied to Upper Yield Stress

Digest of "The Effect of Rate of Stress Application and Temperature on the Upper Yield Stress of Annealed Mild Steel", by J. A. Hendrickson and D. S. Wood, ⊕ Preprint No. 27, 1957.

Previous investigations have shown that mild steel exhibits a distinct delay time for the initiation of yielding when subjected to rapidly applied constant tensile stresses in excess of the static upper yield stress. Also, the basic concepts of a dislocation theory of yield point phenomena have been developed.

The dislocation theories may also


These parts are IMMUNE TO MOLTEN ALUMINUM
Molten aluminum can't wet, can't harm the precision-formed parts shown here. These parts and fittings for aluminum die-casting and direct-chill castings are all made of REFRAX® silicon-nitride-bonded silicon carbide. They are Carborundum's answer to the need for a material that can be formed into intricate parts with outstanding corrosion resistance far above normal melting temperatures. REFRAX shapes are solving many problems in aluminum holding furnaces and aluminum alloying furnaces (including reverberatory and induction).
Consider the value of these other properties in your operation: Tolerances of ± .0005 in./in.; a modulus of rupture of 5600 psi at 2450°F (even the best heat resistant alloy melts below this temperature); and high heat conductivity that approaches that of chrome-nickel steel. Write today for product bulletin and technical articles on REFRAX materials. Refractories Division, The Carborundum Company, Perth Amboy, New Jersey, Dept. MM117.
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Upper Yield Stress . . .

be employed to derive expressions for the upper yield stress and the time of yielding as functions of temperature under types of loading other than rapidly applied constant stress.

Two theoretical predictions of the upper yield stress of an annealed low-carbon steel as a function of rate of stress application and temperature are presented in this paper. Both predictions are based upon the basic concepts of the dislocation theory of yield point in body-centered cubic metals containing interstitial solutes. The difference between the two predictions arises from differences in the various assumptions and approximations which are made in the derivations. Quantitative predictions of the upper yield stress are obtained by evaluating the undetermined constants of the two forms of the theory by means of experimentally determined values of the delay time for yielding under constant stress.

The upper yield stress of an annealed low-carbon steel was determined experimentally under various constant rates of stress application ranging from about 10^2 to 10^7 psi. per sec. at temperatures of −110 and −200° F. The steel analyzed 0.17% C, 0.39% Mn, 0.017% P and 0.040% S.

The specimens were annealed by heating at 1600° F. for 50 min. followed by slow cooling in the furnace. The entire annealing treatment was done in an atmosphere of dry hydrogen after all machining operations on the specimens had been completed. The average grain size of the material was A.S.T.M. No. 6.5.

The tensile tests at constant rates of stress application were performed by means of a hydro-pneumatically operated rapid load tensile machine. This machine is capable of rates of load application up to about 10^6 lb. per sec. Since the diameter of the gage section of the test specimen is 0.300 in., the maximum rate of stress application attainable is about 10^7 psi. per sec.

The applied load was determined as a function of time during each test by means of a calibrated dynamometer employing type AB-14,

(*Continued on p.* 188)

one more reason to specify

NATIONAL ELECTRODES

TRADE MARK

IMPORTANT NEW SAVINGS for ELECTRIC FURNACE OPERATORS

PIONEERED BY NATIONAL CARBON COMPANY

Seven ¼" steel rails run length of car sides. Cross-members of 9-gauge steel, wood-faced to prevent gouging, fit into 1" center rail holes to give each compartment a restraining force of 42,000 lbs.

A full load of 18" graphite electrodes and nipples in a Chesapeake & Ohio damage-free gondola car. The car can be unloaded quickly and simply from either end.

Twenty seven 35" x 110" electrodes loaded in a new Union Pacific damage-free gondola car.
Previous gondola car design permitted a maximum load of only fifteen electrodes of this size.

Now, in addition to assuring safe electrode shipments, you can simplify unloading, avoid demurrage and greatly reduce dunnage disposal problems. The reason: new damage-free gondola cars developed jointly by National Carbon Company and the Evans Products Company.

Thanks to an ingenious system of adjustable bracing, these "DF"† gondola cars require minimum dunnage yet carry substantially greater loads than ordinary gondola cars. Unloading from either end of the car is quick and simple. Since cars are not tied up long and average shipments are larger, furnace operators save penalty fees and cut handling costs.

Helping customers cut costs is only one of National Carbon's customer services. Be sure to specify NATIONAL CARBON COMPANY ELECTRODES, product of the nation's foremost electrode producer.

NATIONAL CARBON gives furnace operators . . .

- * Highest uniform electrode quality
- * National service organization
- * Technical electrode program for operators
- * Scientific packaging to assure damage-free delivery . . . to keep electrodes clean . . . to eliminate in-plant handling damage.

†"DF" is a trade-mark of Evans Products Company.

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Upper Yield Stress . . .

SR-4 strain gages. The signal from the dynamometer was amplified and recorded. The time resolution of the recording system is about ± 1 millisec. at the maximum recording rate. The load acting on the specimen at any time could be determined to within an estimated over-all error of about 4%. The onset of macroscopic yielding is characterized by a sudden decrease of load which is readily detectable on the test records.

The low test temperatures were provided by a bath of Freon-12 held in a suitable container surrounding the specimen and portions of the grips. Dry ice in the Freon bath brought the temperature to –110° F., and liquid nitrogen in a concentric container surrounding the Freon bath provided the test temperature of –200° F. An electrical heater in the bath controlled the temperature of the specimen. The total temperature difference along the specimen gage length was less than ± 5° F. for the tests at –200° F., and less than ± 1° F. at –110° F. The temperature variation was ± 10° F. or less during the tests at –200° F. and less than ±1° F. during the tests at –110° F.

The experimental measurements of the upper yield stress as a function of the applied stress rate at the two temperatures are in good agreement with the predictions of both forms of the theory mentioned above. This indicates that the general aspects of the dislocation theory of yielding are correct. The experimental data available at the present time are not sufficient to evaluate the relative merits of the several specific theories which may be constructed by employing different detailed dislocation models. However, these theories are capable of predicting the upper yield stress of a mild steel subjected to various constant rates of stress application and temperatures.

The theory may also be employed to predict the upper yield stress under more complex stress-versus-time conditions. Furthermore, the experimental data required for quantitative evaluation of the theory could be obtained from tests at constant rates of stress application, rather than from delay time measurements. In this case the delay time could be predicted as a function of applied stress and temperature.

D. J. GIRARDI

Deformation of Uranium During Thermal Cycling

Digest of "Microstructural Changes of Uranium Upon Thermal Cycling", by L. T. Lloyd and R. M. Mayfield, Preprint No. 35, 1957.

ONE OF THE important problems encountered by metallurgists working on fuel elements for nuclear reactors is the abnormal macroscopic deformations which occur in uranium and its alloys. The authors studied the microstructural changes accompanying the dimensional changes due to thermal cycling of the orthorhombic phase of uranium. Most investigators agree that this type of dimensional instability arises from intercrystalline stresses devel-

Uranium Deformation . . .

oped by the anisotropic thermal expansion of the orthorhombic phase. Burke, Howe and Lacy ("Dimensional Instability of Uranium," Knolls Atomic Power Laboratory, TID-5044) have proposed a "thermal ratcheting" mechanism which makes the deformation irreversible.

The authors studied three types of uranium – coarse-grained, highly purified uranium, to establish the metallographic aspects of deformation during thermal cycling; fine-grained, high-purity uranium; and some commercial-purity, fine-grained uranium.

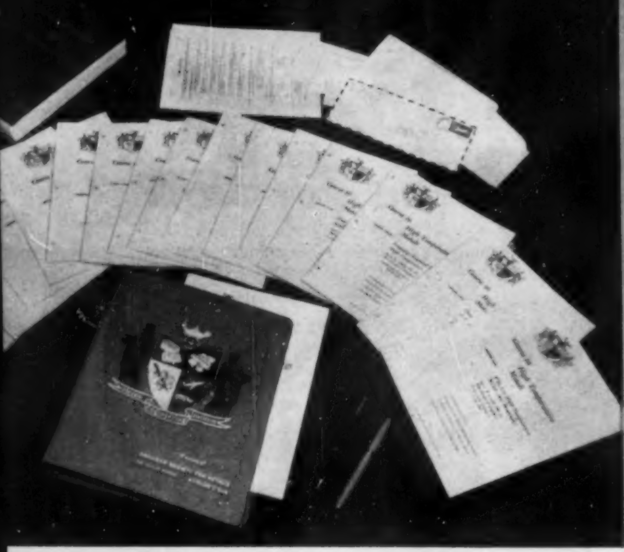
Upon cycling the coarse-grained uranium between room temperature and 500° C. (930° F.), the major intragranular deformation occurred by slip, mainly on (010)–[100] with cross-slip in some grains and some secondary {110} – <110>. There was also an increase in {130} twinned material but no increase in the number of twins. These crystallographic evidences of slip and twinning occurred after the first treatment of 15 cycles and a greater number of cycles did not result in additional mechanisms of deformation–merely an enhancement of the metallographic evidence of deformation. There was also evidence of subgrain formation.

In the fine-grained samples there was evidence of subgrain formation, grain-boundary migration and grain-boundary sliding after thermal cycling as well as slip and twinning. The amount of deformation resulting from twinning was very minor. There was no evidence of voids in the high-purity uranium even after 3000 cycles, but there was evidence of grain growth.

A sample of commercial-grade uranium thermal cycled for 3000 cycles showed a unidirectional growth of approximately six times the sample's original length. The outstanding microstructural change was the presence of an abundance of voids. There was also an increase in grain size but no change in preferred orientation.

The authors point out the close similarity between the deformation mechanisms in thermal cycling of uranium and those in the creep of metals. Both processes are associ-

(*Continued on p.* 196)



Three years of intensive planning have gone into this new and modern approach to home study and in-plant training courses. As a student, you receive the beautiful 3-ring binder pictured above, stamped in attractive red, gold and black with the insignia of the Metals Engineering Institute.

You receive fifteen lessons in each course, lessons that thoroughly cover the study subject in up-to-the-minute detail. Each lesson is distinctively printed and clearly illustrated. When you have completed the course, these 15 lessons and the comments of your instructor will provide a permanent loose-leaf reference.

Another valuable study tool and reference feature of each course is the ASM Metals Handbook, supplied free as a regular part of your course. Upon enrollment, you will receive (1) the ASM Metals Handbook; (2) the attractive MEI Binder; (3) the first two study course lessons, and instructions for study. Then in your own spare time you complete your first lesson, return your quiz questions to the instructor assigned to you at MEI Headquarters. Then you can begin Lesson No. 2. Meanwhile, your MEI instructor goes over your answers to the Lesson No. 1, carefully grades and makes suggestions for you. These suggestions and comments are then returned to you, along with the Lesson No. 3. And so on. You always have a lesson in your hands. You have one going to M.E.I. and M.E.I. has one coming to you. This rotation is maintained to conveniently fit in with your own plans, your own available time.

ELEMENTS OF METALLURGY

Many outstanding authorities have contributed to this popular course edited by Ralph E. Edelman, Chief, Reactive Metals Section, Pitman-Dunn Laboratories, Frankford Arsenal, Philadelphia.

This is a practical course that deals with the behavior of metals in refining, heat treating, fabrication, electroplating and numerous other metalworking operations. It is a course that introduces the student who may have little prior knowledge of chemistry or physics to a down-to-earth study of metallurgy.

Paul R. Brucker, Metallurgist, Crucible Steel Co. of America, Midland, Pa., joins Mr. Edelman in preparation of the first five lessons of "Elements of Metallurgy". *Lesson No. 1* lays the groundwork for an understanding of metallurgy in an examination of the structure of metals, the behavior of atoms and molecules. Following this study of the chemical nature of metals, *Lesson No. 2* concentrates on the physical side and the problems of measurement, expansion, mass and energy, heat transfer and the like.

The chemical changes, or reactions, that take place between elements, between compounds, or between elements and compounds are discussed in *Lesson No. 3*, with *Lesson No. 4* reviewing what happens in any given instance with specific elements in chemical reactions and with the effects of heat and temperature. *Lesson No. 5* points out that the chemical reactions that involve oxides are the foundation for the chemistry of refractories, smelting and combustion, and these are discussed.

Smelting and refractories and metal refining are subjects of *Lessons 6 and 7*, and are prepared by Edward D. Hinkel, Jr., Metallurgist, Carpenter Steel Co., Reading, Pa., with Mr. Edelman. Various smelting processes are described and necessary equipment is illustrated with cut-away charts and pictures. Refining processes that are required to produce a finished alloy from the metal produced by the smelting operations are then presented.

In *Lesson No. 8*, William McNeill, Electrochemist at Frankford Arsenal joins Mr. Edelman in a thorough discussion of electrolytic metallurgical processes, while in *Lesson No. 9*, Harry W. Antes, Metallurgist at Frankford cooperates with Mr. Edelman in an examination of what takes place when refined metals that are poured into ingot molds change from liquid to solid. In *Lesson No. 10*, Leonard Rubin, Research Assistant at Massachusetts Institute of Technology, writes with Mr. Edelman a more detailed discussion of metals structures in this solid state.

Five additional lessons cover heat treatment, precipitation hardening, diffusion and surface treatments, methods of forms and mechanical testing to provide an authoritative study, a practical presentation of a vital area in the metal industry. Mr. Edelman is well qualified to edit this fine course with his experience as Senior Metallurgist, Wright Aeronautical Corporation . . . Staff Metallurgist at Los Alamos Scientific Laboratories . . . Instructor, Metallurgy Extension, Pennsylvania State University . . . prior to his present position with Frankford Arsenal.

HEAT TREATMENT OF STEEL

One of the basic requirements in the processing of steels is their correct and efficient heat treatment. This outstanding, up-to-the-minute steel treating course fills the bill exactly with 15 authoritative lessons prepared by George F. Melloy, Research Engineer, Bethlehem Steel Co., Bethlehem, Pennsylvania.

Scores of pictures, charts and tabular matter are presented by Mr. Melloy in this practical coverage of all important aspects of the Heat Treatment of Steel. You will find this an interesting, helpful study, and a handy, day-by-day reference in the future.

Steel is a versatile material, Mr. Melloy points out in *Lesson No. 1*. He discusses what steel is, what properties make it useful and important, how these properties are measured and evaluated. He covers elasticity, plasticity, tensil testing and other important aspects. *Lesson No. 2* discusses the structure and mechanical properties . . . constitution of steel . . . effect of alloying elements and of heat treatment on mechanical properties.

Lesson No. 3 discusses relationship between structure of steel and its mechanical properties and the two basic methods of controlling structure and hence mechanical properties. *Lesson No. 4* describes annealing of steel—process of heating and cooling to reduce hardness . . . discusses procedures of altering and controlling structure of steel.

Hardening of steel is the subject of *Lesson No. 5*, and Mr. Melloy points out that only in modern times have these principles been understood. Maximum benefits from hardening were not realized until fairly recently. He shows how you can take full advantage of steel with proper hardening processes. *Lesson No. 6* continues a discussion of hardness and the factors involved . . . tests . . . and application of hardenability data.

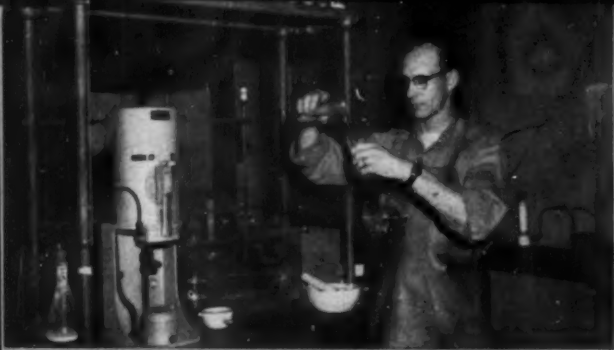
Factors affecting hardness and hardenability are presented in *Lesson No. 7*, and include effects of carbon . . . alloying . . . quenching and miscellaneous factors. *Lesson No. 8* brings you up-to-date on tempering . . . its three stages . . . effect of temperature and time, of chemical composition and structure . . . of cooling practices.

Surface hardening of steel is discussed in *Lesson No. 9* and includes flame, induction and liquid salt hardening. Heat treatment of cast iron and cast steel described in *Lesson No. 10*, with *Lesson No. 11* discussing protection during heat treatment against decarburization and scaling. Heat treating furnaces, fuels and temperature control are reviewed in *Lesson No. 12*.

Lesson No. 13 outlines the failures and defects to look out for in heat treatment, and *Lesson No. 14* describes grain size—its control and effect. Final *Lesson No. 15* deals with the important area of tools steels—water hardening, shock resisting, nondeforming, hot work and high speed steels.

Mr. Melloy's work on this outstanding course is backed by long years of experience at Bethlehem Steel Company. He is a graduate of Lehigh University with a degree in Metallurgical Engineering, has been an instructor at the Bethlehem Center of the Mineral Industries Extension Services, Pennsylvania State University.

THESE COURSES



". . . Makes my work more interesting . . ." says Student

Glen C. Boyce, Chemist and Foreman of the Iowa Malleable Iron Co., Fairfield, Iowa, selected "Elements of Metallurgy" as his M.E.I. study. He writes "I am enjoying this course very much. The fact that the study material parallels my work makes both my work and studies a *great deal more interesting."*

Executives, engineers, supervisors and production men are taking this in-plant training course on the "Elements of Metallurgy" at Cleveland Pneumatic Tool Co., Cleveland. Dr. Anton deSales Brasunas, Director of Metals Engineering Institute is teaching this class of 22 students. Training Directors and employers have shown great interest in these metals training courses for management, engineering, production and sales executives.

HIGH TEMPERATURE METALS

One of the most timely home study courses available anywhere . . . this course on High Temperature Metals by Dr. C. L. Clark, Metallurgical Engineer, Timken Roller Bearing Co., Canton, Ohio, authoritatively covers a broad, vitally essential area.

Fifteen lessons are packed with updated information, filled with 287 helpful illustrations. Keyed to references in the ASM Metals Handbook (a part of the study course), Dr. Clark provides a step-by-step climb to expert knowledge.

Jet engines, modern automobiles . . . the electricity you use . . . the high quality gasoline . . . all these are made possible by high temperature metals, and the surface of tomorrow's use is yet to be scratched. Here is a field where the *expert you can become* knows no limits.

Lesson No. 1 traces the growth of high temperature metallurgy, discusses today's most pressing problems in this interesting field. Relates the importance of high temperature metals in three major metal using industries. *Lesson No. 2* demonstrates, simply and practically, the many tests that can be made . . . their importance. *Lesson No. 3* shows the relationship between room temperature properties to high temperature alloys . . . carbide formation . . . temper brittleness . . . stability. *Lesson No. 4* goes into corrosion . . . hot hardness . . . thermal shock resistance. *Lesson No. 5* discusses allowable working stresses . . . factor for safety . . . design for long service life . . . ASME stresses . . . Lab Data. *Lesson No. 6* deals with melting charge constituents . . . chromium, molybdenum, nickel, titanium, tungsten, vanadium, cobalt, silicon, and many others. *Lesson No. 7* presents the factors that influence high temperature strength . . . *No. 8,* the low and intermediate alloy steels . . . *No. 9,* the straight chromium stainless steels . . . *No. 10,* the austenitic iron-nickel-chromium steels . . . *No. 11,* high temperature superalloys . . . *No. 12,* the low alloy steel for highly stressed high temperature applications . . . *No. 13,* representative service failures . . . *No. 14,* metal properties at processing and fabricating temperatures . . . *No. 15,* selection of alloys for specific application. These helpful, practical lessons . . . the suggestions and comments of your M.E.I. Instructor will bring you up-to-date on high temperature metals technology.

The quality and authority of this course is the natural result of its learned preparation by Dr. Clark, who is a graduate of the University of Michigan with BSE, MSE and PhD degrees. After lecturing in Metallurgical Engineering at the University, he joined the Steel and Tube Division of the Timken Roller Bearing Company, where he is now Metallurgical Engineer, Special Steel Developments. He has developed a number of alloys, holds several patents, has published 100 papers. He is active in many societies and on many technical committees, has received a citation from his University as a distinguished alumnus.

TITANIUM

Millions of dollars have been poured into research and development of Titanium in the United States, England, Japan and other countries since it was first industrialized in 1948. Here is an important new metal of industry . . . one of the most interesting . . . one where firsthand information can be vital to the individual who wants to grow with this great industry.

Authorities throughout the world have been generous in their aid in creating this titanium course . . . it has been prepared by experts throughout the United States, with editorial direction by Dr. Walter L. Finlay, Vice President and Manager of Research, Rem-Cru Titanium, Inc., Midland, Pa.

This course summarizes the metallurgy and technology of titanium . . . provides a detailed picture of where titanium is today, the direction in which it is headed. Each of the 15 lessons covers an important aspect of titanium technology.

In *Lesson No. 1,* Dr. Finlay describes characteristics of titanium, its properties . . . strength-to-weight, tensile strength, crippling strength, corrosion resistance, thermal conductivity and expansion . . . and many applications.

R. L. Powell, Supervisor, Process Research Division, Titanium Metals Corporation of America, Henderson, Nevada, prepared *Lesson No. 2* on the extractive metallurgy of titanium. He discusses production from titanium dioxide, from titanium tetrachloride . . . describes purification, chemical reduction, electrolytic reduction.

Lesson No. 3, by Dr. Finlay, surveys titanium-base alloys . . . gives the ABC's of titanium alloys . . . their structure, heat treatment, etc. In *Lesson No. 4,* Dr. Robert I. Jaffee, Chief, Nonferrous Physical Metallurgy Division, Battelle Memorial Institute, discusses physical metallurgy . . . describes important alloying elements and major contaminants. Dr. Jaffee continues in *Lesson No. 5* with a discussion of beta transformation, heat treatment and thermal stability.

Physical and mechanical properties of titanium are presented in *Lesson No. 6* by D. R. Luster, Chief Supervisor, Research Department, Rem-Cru Titanium, Inc. This lesson reviews what is now known of these important properties and indicates the probable properties that can be expected from yet-to-be developed alloys.

Mr. Luster discusses the metallurgy of titanium in *Lesson No. 7,* and in *Lesson No. 8,* Dr. Finlay describes melting, casting and the powder metallurgy of titanium. Mill processing is covered in *Lesson No. 9* by two experts . . . Dr. Lee S. Busch, Director of Research and Richard J. McClintick, both of Mallory-Sharon Titanium Corporation, Niles, Ohio.

Machining and grinding of titanium is detailed in *Lesson No. 10* by John P. Catlin, of Rem-Cru Titanium, Inc., and in *Lesson No. 11,* George C. Kiefer, of Allegheny Ludlum Steel Corporation, Brackenridge, Pa., discusses corrosion resistance, surface conditioning and chemical analysis.

Final four lessons give outstanding coverage of joining operations, by Glen E. Faulkner, Research Engineer, Battelle Memorial Institute . . . airframe designs, manufacture and uses, by Gordon A. Fairbairn, Supervisor, Materials and Processes, North American Aviation, Inc., Los Angeles . . . titanium jet engine design, by M. E. Cieslicki, Supervisor, Materials Control, General Electric Company, Cincinnati . . . latest developments and trends, by W. Stuart Lyman and E. W. Cawthorne of Titanium Metals Laboratory.

Here is a study course written by outstanding experts, edited by a recognized authority, Dr. Finlay, a graduate of Lehigh University, with a Master's Degree and a Doctor's Degree in Metallurgical Engineering from Yale University. Prior to his association with Rem-Cru, Dr. Finlay was Supervisor of Chemical and Metallurgical Research for Remington Arms Company.

NOW AVAILABLE

Today, the story of the Metals Engineering Institute is dramatized in the long columns of classified advertising. Trained men—*wanted!* Engineers—*wanted!* Industry needs skilled help, needs it badly—and nowhere is this need more severe than in the great industries that produce and use metals.

In a world of metals, there is an insistent demand for men who *know* metals. The American Society for Metals recognized this need three years ago. It studied these requirements of the industry it had served for forty years. It thoroughly investigated how these training requirements were being served.

As a result of this intensive investigation . . . of consultation with industry . . . the Society created the Metals Engineering Institute and projected a series of study courses to meet modern training requirements of industry. In the years since formation of MEI, the outstanding experts and authorities who have long known and respected the American Society for Metals have been engaged in the preparation of nearly two-score metals courses. Some of the most important of these courses are ready now—more will be ready soon.

Today, then, men who want to get ahead in the giant metal industry . . . men who *want* to know about metals . . . men like you . . . can study, in your own spare time, the authoritative, the new shaped-by-industry courses—at home or on-the-job.

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Anton deS. Brasunas

Anton deSales Brasunas, *Director*
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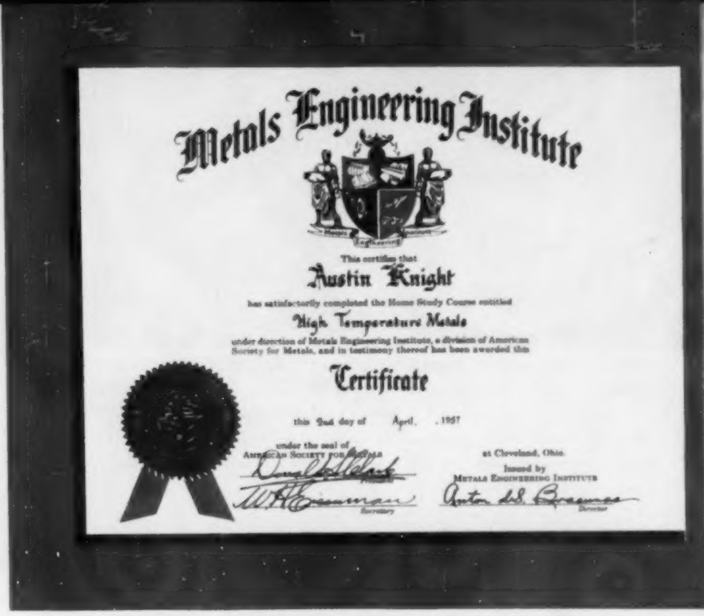
Dr. Anton deSales Brasunas was appointed Director of the Metals Engineering Institute after a long search for just the right man who, by education and experience, would most ideally qualify for this important post. Dr. Brasunas came to MEI from the University of Tennessee where he was associate professor of metallurgical engineering. Prior to that time, he was associated with the Oak Ridge National Laboratory and with Battelle Memorial Institute. He is a graduate of Antioch College, received his MSc. degree from Ohio State University, his Sc.D degree from Massachusetts Institute of Technology.



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Uranium Deformation . . .

ated with intragranular slip and in some cases twinning, subgrain formation, grain-boundary migration and grain-boundary sliding. The stresses which cause the deformation on thermal cycling arise from the anisotropic thermal expansion of uranium and the disorientation between adjoining grains and the relative position of the grain boundary.

The work performed by Mayfield, "Effects of Cycling Variables Upon Growth Rate of 300° C. Rolled Uranium", Preprint No. 37, 1957, is cited to illustrate the similarity of creep deformation and thermal cycling deformation. For example, Mayfield found maximum growth in highly textured uranium with slow heating and fast cooling rates, whereas fast heating and slow cooling resulted in minimum growth. Presumably the longer period of time associated with slow heating enables the material to elongate by creep to a greater extent under the internal stresses.

The large unidirectional growth can be likened to the dimensional changes which occur upon application of an external tensile stress in a creep test. The higher the upper cycling temperature for a given temperature range, the greater the growth, similar to the higher creep rates which occur at higher creep temperatures. Also if the upper cycling temperature is below 350° C. (660° F.), the thermal cycling growth is small and this would correspond to temperatures below which polygonization does not occur and creep is negligible.

The occurence of voids in the commercially pure material in a sense corresponds to the voids often observed during creep testing of impure material and consequently can probably be related to the chemical purity of the uranium. It would be interesting to see the work followed by a paper on the creep properties of uranium.

J. H. Bechtold

Machinability of Leaded Steels

Digest of "The Machinability of Type A Leaded Steels", by E. J. Paliwoda, Preprint No. 42, 1957.

Machinability indices of Type A leaded steels obtained from several production sources are reported. These, together with machinability indices of A.I.S.I. C 1213 steels are plotted against percent silicon content and percent carbon.

It is pointed out that mass of lead inclusions appears to be dependent on the nature of sulphide inclusions. Fine lead tails are associated with fine stringer-like sulphides.

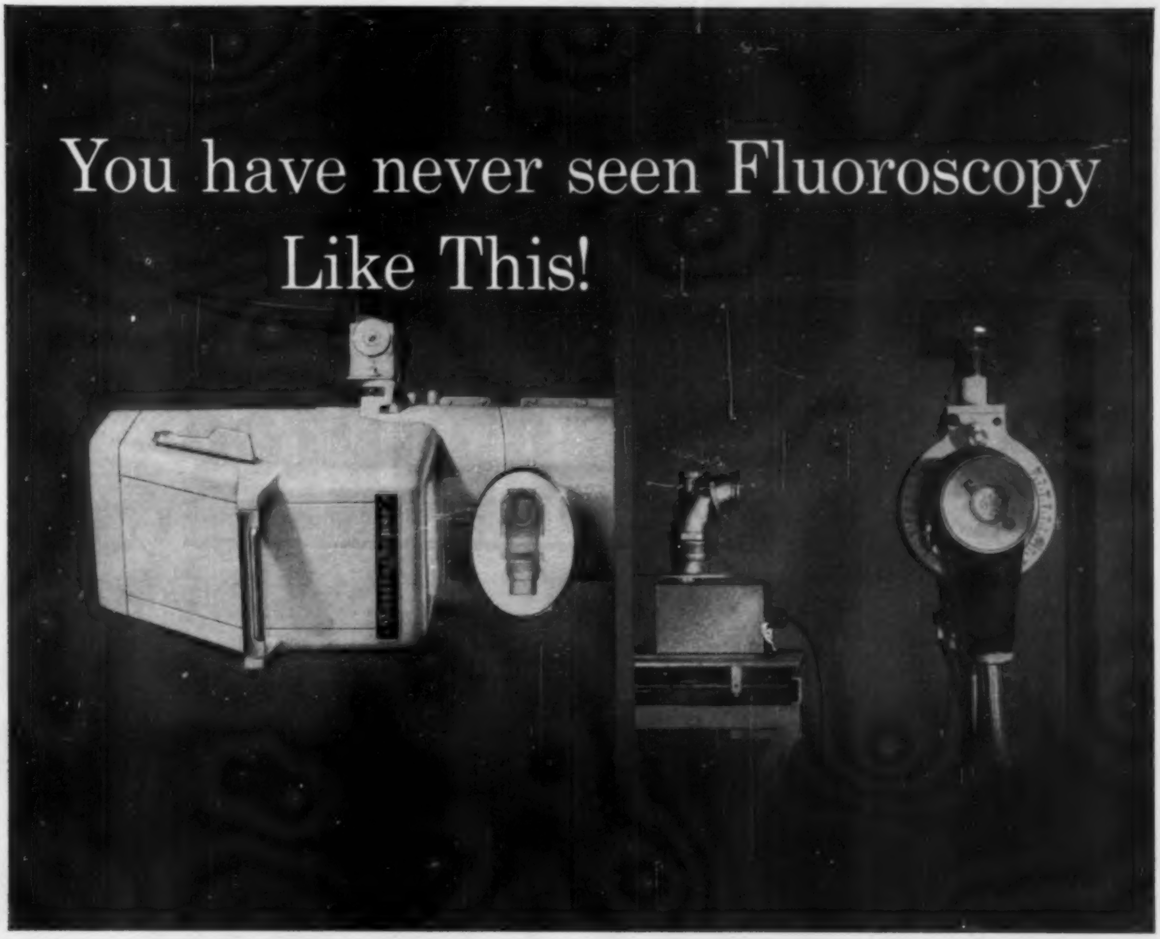
Tests were aimed at determining the highest turning speeds possible without exceeding prescribed wear of the cutting tool. This highest turning speed is reported as the machinability index.

The microdispersion of the lead in the steel was investigated, and illustrated by microradiographs. It is interesting to note that virtually all of the visible lead or lead compound particles are associated with sulphide inclusions.

Since shape formation and surface finish were not measured, the effect of phosphorus and nitrogen on machinability index was not measured in these tests.

Chemical composition variations in carbon, lead, sulphur, silicon and manganese affect the machinability

(*Continued on p. 200*)



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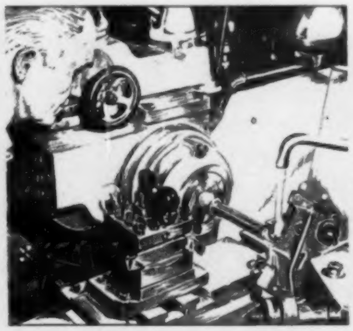
Leaded Steels . . .

of the leaded high-sulphur steel in a fashion parallel to the effect of these elements in regular screw stock.

As carbon content decreases, machinability increases in both leaded and C 1213 steel: A 0.01% decrease in carbon adds 6 index points to the machinability of Type A leaded steel, and a 0.01% decrease in carbon adds 8½ index points to the machinability of C 1213 steel.

As lead and sulphur contents increase, machinability increases: A 0.01% increase in lead adds 1 index point to the machinability of Type A leaded steels; a 0.01% increase in sulphur in regular openhearth steel



adds 1½ points to the machinability index; a 0.01% increase in sulphur in leaded stock adds 1 index point to the machinability index.

As silicon increases machinability decreases in both steels: A 0.01% decrease in silicon adds 13 points to the machinability index of the leaded steels, and a 0.01% decrease in silicon adds 18 points to the machinability index of C 1213.

As manganese decreases, a slight increase in machinability is reported. (It has been the reviewer's experience that some manganese improves machinability from the chip formation standpoint but quite probably would be disadvantageous under the present test.)

Since chip formation and surface finish were not measured the effect of phosphorus and nitrogen was not measured in these tests.

In tests reported, the relationship of chemical composition variations to machinability index is expressed as: Machinability index = 265 − 600(% C) − 1300(% Si) − 100(% Mn) + 100(% S) + 100(% Pb).

E. J. WELLER

Hardness of Zirconium-Uranium Alloys up to 1650° F.

Digest of "A Hot-Hardness Survey of the Zirconium-Uranium System," by W. Chubb, G. T. Muehlenkamp and A. D. Schwope, ⊛ Preprint No. 2, 1957.

The use of zirconium as a structural material in nuclear reactors, and particularly as an alloying element or a cladding material for the uranium fuel, has prompted a survey of the mechanical properties of zirconium-uranium alloys. Hardness measurement was chosen because of its simplicity compared with other test methods. Hardness measurements at elevated temperatures may be of particular value (*a*) in indicating the maximum useful temperature for an alloy, and (*b*) in acting as a guide for fabrication practices such as hot rolling and forging. The principal limitation of hardness as a property is that it provides relatively little information about ductility.

Hot hardness measurements were made in an apparatus capable of handling specimens at temperatures up to 1000° C. (1830° F.) and in a vacuum of less than 5 μ Hg. The specimen was raised against a sapphire-tipped column that the specimen lifted and supported for aproximately 10 sec. The column weighed 1 kg. and the sapphire tip had the Vickers pyramid shape; all hardness values were reported as diamond pyramid hardness numbers.

The hardness survey was conducted on the pure metals and on 11 alloys, spaced approximately at equal intervals in atomic per cent across the phase diagram. Alloys were prepared by arc melting or by induction melting, with no hardness trends being attributed to these differences in preparation. All alloys were hot rolled to ⅛-in. sheet in the gamma range at temperatures between 700 and 930° C. (1290 and 1705° F.). Prior to testing, they were heated for 24 hr. at 575° C. (1065° F.). Hardnesses were determined at room temperature, 300,

Zr-U Alloys . . .

500, 600, 650, 700, 750, 800, 850 and 900° C. (570, 930, 1110, 1200, 1290, 1380, 1470, 1560 and 1650° F.).

At all temperatures, the hardness tended to be lowest for the pure metals, increased rapidly with small alloying additions, and then increased more slowly to a maximum at some intermediate composition.

Notable exceptions to this generalization occurred at 700 and 800° C. (1290 and 1470° F.) for zirconium-rich alloys and at 700° C. (1290° F.) for uranium-rich alloys. Zirconium-rich alloys consisted of two phases at 700 and 800° C. (1290 and 1470° F.), and the presence of increasing amounts of the soft gamma solid solution phase with added uranium resulted in an initial hardness decrease. The gamma phase itself became harder with increasing uranium content and it eventually passed through a maximum in hardness midway in the composition range. Uranium-rich alloys up to about 5 at.% zirconium at 700° C. (1290° F.), contained the hard beta uranium structure, which was far the hardest of all the zirconium-uranium alloys in the temperature range of 650 to 760° C. (1200 to 1400° F.). Alloys containing beta uranium undoubtedly are more difficult to work than other alloys in this system.

The maximum hardness at room temperature was at about 60 at.% uranium (80% by weight). With increasing temperature up to 600° C. (1110° F.) this maximum shifted to about 30 at.% (50% by weight). From 500 to 600° C. (930 to 1110° F.) it corresonded to the approximate composition range of the delta phase reported by Holden and Seymour (*Transactions*, A.I.M.E., Vol. 206, 1956, p. 1312).

As the gamma phase began to appear at temperatures of 600° C. (1110° F.) and above, all alloys decreased rapidly in hardness. Typical hardness numbers for a 50 at. % alloy were 360 D.P.H. at room temperature, gradually decreasing to 230 D.P.H. at 500° C. (930° F.), sharply dropping to 74 D.P.H. at 600° C. (1110° F.) and then 15 at 650° C. (1200° F.), after which the hardness gradually decreases to 8 at 900° C. (1650° F.).

DAVID A. THOMAS

Quench-Aging Behavior of Ferrite Containing Carbon and Nitrogen

Digest of "Morphological and Phase Changes During Quench-Aging of Ferrite Containing Carbon and Nitrogen", by G. Lagerberg and B. S. Lement, ⊕ Preprint No. 33, 1957.

THE ALLOYS used in this investigation were of high purity in the following compositions: Fe-C (0.016% C), Fe-N (0.084% N), and two Fe-C-N alloys (0.021% C, 0.028% N, and 0.023% C, 0.011% N respectively). Their quench-aging behavior was studied by light metallography, electron diffraction and electron metallography.

Experimental carburizing, decar-

Tool Steel Topics

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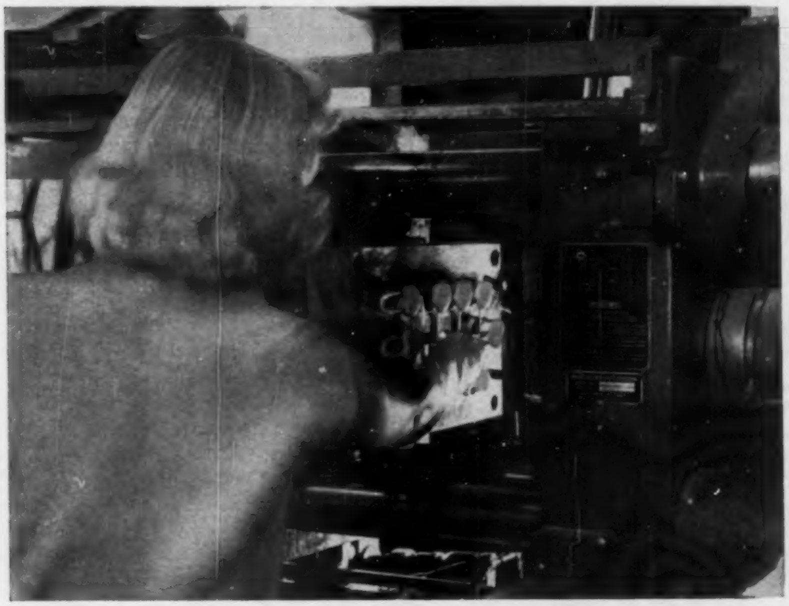
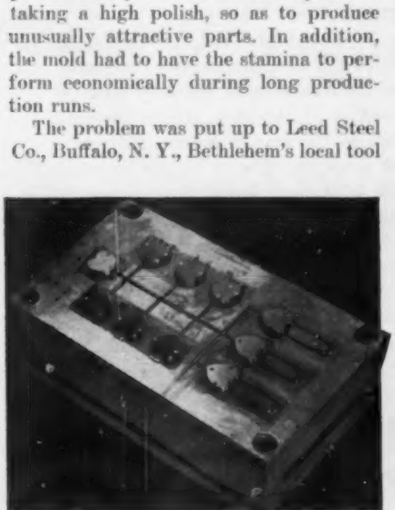


Lustre-Die Takes High Polish For Molding Plastic Rattles

Shreve Molded Products, Youngstown, Ohio, needed an injection mold for the production of heart-shaped parts for baby rattles, using acetate and styrene plastics. They wanted a mold capable of taking a high polish, so as to produce unusually attractive parts. In addition, the mold had to have the stamina to perform economically during long production runs.

The problem was put up to Leed Steel Co., Buffalo, N. Y., Bethlehem's local tool steel distributor. Their recommendation was Lustre-Die tool steel. It proved to be an excellent choice, too, for the mold, which was produced by Tri-Penn Tool Co., Erie, Pa., has been satisfactory in every way.



Lustre-Die is ideal tool steel for producing plastic parts because its properties enable it to take an unbelievably bright, mirror-like polish. Not only does Lustre-Die have the proper basic analysis for working with plastics—we even go a step beyond that by adding alloy fortification. We also build up the steel's excellent properties by oil-quenching and tempering, so that it can be furnished ready for machining and polishing.

Lustre-Die is made in the electric furnace, and is carefully inspected to insure cleanliness. It has a minimum of inclusion-causing additions. Besides, modern inspection methods hold injurious porosity to the minimum.

If you have any questions about Lustre-Die, or if you would like to give it a trial run, your Bethlehem tool steel distributor will be pleased to assist you.

BETHLEHEM TOOL STEEL ENGINEER SAYS:

It Pays to Keep Tools Sharp

In many shops, resharpening of production cutting tools is sadly neglected. In an effort to keep output high, too many tools are kept in use beyond the point where the cutting edges become excessively dull.

What happens when edges are dull? The dull edges cause an increase in the service load of the shearing or cutting operation. If the dullness is carried to extremes, tools break. Dull edges also produce rough surfaces on the parts, which may lead to rejections due to defects, or because the permissible tolerances have been exceeded.

Should resharpening be delayed too long, it may be impossible to recondition a tool properly, as deep spalls, cracks and gouges cannot be removed. Usually there is an economic balance point where it is best to resharpen, and for each operation this should be determined in advance. Tools should also be inspected regularly, to prevent excessive dulling. Intelligent use of preventive maintenance of cutting edges can work wonders in providing longer tool life and fewer broken tools.

Bearcat Puts Square Holes in ½-in. Plate

In this operation, photographed at Frink Sno-Plows, Inc., Clayton, N. Y., Bethlehem Bearcat is putting 11/16-in. square holes in carbon-steel plate, used as cutting edge of snow plows. Though the steel plate is 1/2 in. thick, the average life of each punch is 5500 holes.

Quench-Aging . . .

burizing and nitriding treatments were performed on $\frac{1}{8} \times \frac{1}{4}$-in. bars, and on $\frac{1}{4}$-in. diameter rounds of various lengths. The bars were annealed for 20 min. at 860° C. (1580° F.) in Vycor tubes to obtain uniform grain size. The carburizing treatment consisted of a 24-hr. cycle at 675 to 710° C. (1250 to 1310° F.) in hydrogen saturated (at room temperature) with normal heptane. Nitriding treatment was 48 hr. at 580° C. (1075° F.) in ammonia-hydrogen mixtures. About 1/64-in. was machined from the surfaces of carburized samples to remove cementite layers.

The Fe-C-N alloys prepared by alternately nitriding and carburizing, used successively shorter treatment times. The final treatment was carburizing. All samples were homogenized. Carburized samples were homogenized for 20 hr. at 720° C. (1330° F.) in Vycor tubes, and nitrided samples were heated 24 hr. in nitrogen at 580° C. (1075° F.). The ternary samples were held at 710° C. (1310° F.) in nitrogen for 24 hr. All solution treatment was done in nitrogen for 15 min. at 715° C. (1320° F.). Samples were then quenched in 10% aqueous sodium hydroxide at about 0°C. (32° F.). Aging treatments were performed in oil or salt baths at 90 to 472° C. (195 to 880° F.).

Metallographic preparation of the specimens began with electrolytic polishing using 19 parts glacial acetic acid to one part perchloric acid. Current densities were 1 amp. per sq. cm. and polishing times 20 to 30 sec. Specimens examined with the light microscope were etched with 1% Nital and then viewed under slightly oblique illumination.

Replicas for electron metallography were dry stripped from etched specimens. They were then rotary shadowed in vacuum, using chromium. The shadowing angle was about 27°.

Reflection electron diffraction measurements were also made on polished and etched surfaces, substituting a diffraction lens for the projector lens of the electron microscope. The electron beam was reflected off the specimen surfaces at a very low incident angle. This allowed protruding particles such as nitrides and carbides to give more intense diffraction patterns than the matrix. The voltage employed was 60 kv., corresponding to a wave length of 0.049°.

The authors came to the following conclusions:

1. The initial stage of aging at relatively low temperatures consisted of the formation of apparent films of various thicknesses at sub-boundaries in the ferritic matrix, indicative of a subgrain size of 10^{-4} to 10^{-5} cm. On continued aging, these apparent films were supplanted by platelets of a metastable phase. No comment was made as to the composition of the apparent films.

2. Depending on the type of supersaturation of the ferrite, the stages of aging were:

Ferrite supersaturated with carbon → ϵ-carbide → cementite.

Ferrite supersaturated with nitrogen → α''-nitride → γ' nitride.

(*Continued on p. 208*)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Quench-Aging . . .

Ferrite supersaturated with both carbon and nitrogen → ϵ-carbonitride → cementite.

At relatively high aging temperatures some evidence of direct formation of the stable precipitate was obtained.

3. In the Fe-C alloy, the transformation of ϵ-carbide to cementite occurred after virtually all the carbon had precipitated from the supersaturated ferrite solution.

4. The ϵ-phase that formed in the Fe-C-N alloys was more stable than that formed in the Fe-C alloy. This was explained by the increased nitrogen content.

5. In Fe-C-N alloys the presence of nitrogen apparently promoted the formation of relatively large plates of cementite constituents.

S. T. Ross

High-Temperature Hardness Tester

Digest of "Apparatus for Determining the Hardness of Metals at Temperatures up to 3000° F.", by M. Semchyshen and C. S. Torgerson, ⊕ Preprint No. 12, 1957.

A relative evaluation of the strength of metals and alloys at high temperatures may be obtained by comparing their hardnesses at temperature. A simple apparatus for impressing microhardness indentures in metals at temperatures up to 3000°F. and in an inert atmosphere is described. The test specimens are 3/16 to ⅜ in. thick and ¼ to 2 in. in diameter, but the size may be modified with the use of suitable fixtures.

The authors have made as many as 40 indentures on two small pieces held in one fixture. The indentor is a synthetic sapphire mounted in a molybdenum rod and dead-weight loaded from the exterior of the furnace through a water-cooled bearing. Multiple indentures are made possible by the rotation of the anvil whose axis is parallel but laterally displaced from the indentor axis.

The data obtained by the authors using this apparatus were sufficiently sensitive to indicate the change in hardness which occurs when iron transforms from alpha to gamma.

F. J. Anders

Growing Cadmium Crystals From Vapor

Digest of "Growth of Cadmium From the Vapor", by J. E. McNutt and R. F. Mehl, ⊕ Preprint No. 6, 1957.

Of the varieties of methods available for growing metal crystals, one of the simplest—growth from the vapor phase—was selected by the authors for study. High-purity cadmium was the metal used.

Experiments were carried out in a totally enclosed system, the reservoir of cadimum being heated with an external tin bath, and the vapor condensed on a Kovar surface by differential cooling with a gas stream.

Transverse growth was accurately measured with an optical fiducial system, while changes in height were

with quality and dependability as bywords . . .

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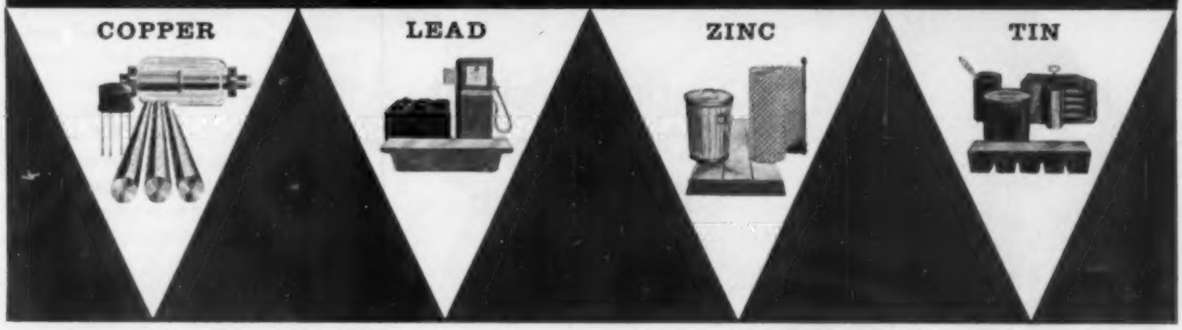

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Crystal Growth . . .

followed by interferometric techniques with a sensitivity of 300 Å.

Thirteen experiments are reported, encompassing metal deposition over a thermal range of 288 to 356°C. (550 to 673° F.), the vapor pressures varying from 0.026 to 0.35 mm. Hg.

The cadmium crystals grew by step formation of basal planes, with hexagonal symmetry. "Ridge boundaries", defined as discrete, straight boundaries across a crystal separating two regions of slightly differing orientation, were noted. This type of region often served as the high energy point of nucleation for successive step growths.

There was no evidence of ridge boundary movement, nor of rational crystallographic directions.

Contrary to classical theory, new monolayers did not generally nucleate on the base crystal away from the edges. On the majority observed, steps appeared first at edges of basal surfaces where adjacent crystals touched. There was no periodicity or height consistency in new step formation—again contrary to expectations.

Propagation of steps occurred in many modes: continuous growth of large steps; extension growths of small steps; splitting into smaller steps with variant growth characteristics; and formation of sloped growth fronts. An interesting phenomenon was observed when a sloping growth front issuing from steps moved across a surface. They appeared to encounter points over which they could not move, causing a "wake" as the front moved past. The apex of the "wake" always pointed into the moving front, and the edges of the "wake" made crystallographically accurate 60° angles with the crystal sides. No explanation of this phenomenon is presented.

Data pertaining to rates of deposition and crystallographic directions are included. There is no evidence that any growth resulted from screw dislocations.

J. L. Wyatt

Dimensional Stability of Wrought Uranium

Digest of "Effects of Fabrication and Heat Treatment Variables Upon the Thermal Cycling Behaviour of Uranium", by S. T. Zegler, R. M. Mayfield and M. H. Mueller, Ⓐ Preprint No. 56, 1957.

The dimensional instability of wrought uranium under thermal cycling and irradiation has presented a difficult problem in the design and operation of solid fuel reactors. Information on the mechanism responsible for the dimensional changes and methods for minimizing or preventing them is now declassified.

The present paper is concerned chiefly with the effects of a number of fabrication variables including rolling temperatures, reductions and pass sequences and heat treating factors. It is based on work conducted at the Argonne National Laboratory.

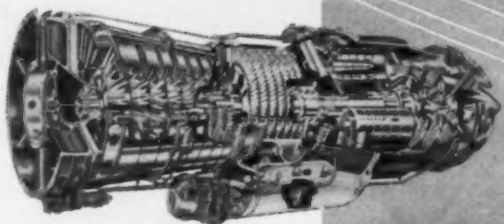
The influence of rolling temperature on thermal cycling was insignificant below the recrystallization temperature, but this variable had important effects when high alpha-

Precision Brazing at PRATT and WHITNEY AIRCRAFT

Relies on R-F Induction Heating With

ML-5668*

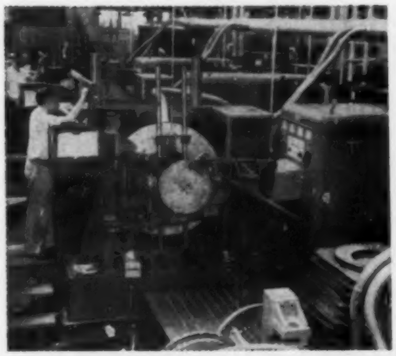
Industrial Electron Tube



J-57, one of the most famous jet engines in the world . . . its low compressor shrouds and blades, center, are brazed with equipment using Machlett ML-5668 industrial electron tubes.

Compressor shrouds for the famous J-57 jet engine are precision brazed with r-f induction heat at Pratt & Whitney Aircraft, East Hartford, Connecticut. R-F power, reliably provided by Machlett electron tubes, permits Pratt and Whitney to obtain the same heat pattern and uniform heat cycle at the root and tip of each blade. A two minute cycle brazes both blade ends simultaneously.

***Machlett induction heater triodes are original components in over 85% of the induction heating equipment models now available in the 5kW to 100kW power output range.**



A battery of induction heaters is used in the assembly of Pratt and Whitney's low compressor shroud for the J-57 jet engine.

*The ML-5668 electron tube was designed by Machlett specifically for heavy duty industrial applications.

MACHLETT

FIRST IN INDUSTRIAL ELECTRON TUBES

MACHLETT LABORATORIES, INC.
Springdale, Connecticut

Wrought Uranium . . .

phase temperatures were attained in the heating cycles. Rolling temperatures of 600° C. (1110° F.) and 640° C. (1185° F.), which are well above the recrystallization temperature, afforded substantially less growth than was observed after rolling at lower temperatures such as 300° C. (570° F.).

Improved performance of metal rolled at the lower temperatures was also obtained by subsequent annealing at temperatures producing recrystallization and grain growth. On the other hand, the dimensional instability was aggravated by increasing reduction and the resultant accentuation of rolling texture. These observations appeared consistent with the conclusion that the amount of growth increases with the degree of preferred orientation and with decreasing grain size.

Heat treating in the beta range for sufficient time to completely transform the material was found to reduce growth substantially. The behavior of the beta-treated uranium was dependent on the conditions of thermal cycling, varying from slight growth to slight shrinkage with changes in heating rate. The degree of surface wrinkling appeared related to the alpha grain size.

H. Y. Hunsicker

Yield Point in Mild Steel at Low Temperatures

Digest of "Some Aspects of Preyield Phenomena in Mild Steel at Low Temperatures", by W. S. Owen, M. Cohen and B. L. Averbach, Ⓐ Preprint No. 9, 1957.

Few metallurgical phenomena have been the subject of more research over a longer period of time than the yield point phenomenon in mild steel. Like many other metallurgical phenomena the yield point in mild steel seems to become more complex as we learn more about it.

The authors studied the sequence of events that occur before gross or discontinuous yielding takes place at room temperature and −196° C. (−320° F.). If a specimen of mild steel is loaded to a constant stress somewhat below the upper yield point and the nonelastic strain measured as a function of time, three distinct stages can be observed in the yielding process. First, a "microstrain" stage in which the strain increases rapidly with time but levels off at a constant value of not more than 50×10^{-6}. Second, a "microcreep" stage in which the strain is time dependent and precedes gross yielding. Third, a "Luder's strain" stage which is usually taken as the beginning of gross, discontinuous yielding.

In order to study these various stages of yielding, the authors used both constant-load strain-time tests —in a way low-temperature creep tests — and standard tensile tests in which the specimens were rapidly loaded to a predetermined load, held for a constant time and then unloaded. From these tests they determined the elastic limit, or the stress at which microstrain begins; the amount of microstrain; the stress at which the "micro-creep" rate is 10^{-6} per min.; the amount of "microcreep"; and the yield strength above which a marked increase in plastic strain rate and "Luder's bands" occurs. These various stages were studied as a function of ferrite grain size, austenitizing temperature and in two steel compositions.

At −196° C. (−320° F.) the various stages of yielding are much more evident than at room temperature, particularly the micro-creep stage which is almost unobservable

Getting specific about gravity!

Falling apples fascinated Sir Isaac Newton. No doubt he enjoyed a few of them while devising his famous gravitational formulas. Newton's concern was with what came down, whereas aviation engineers today are primarily concerned with what goes up. Even so, the gravitational challenge is the same.

A jet plane, intercontinental missile—or anything that moves — usually leaves the design stage too heavy for optimum performance. To be specific — the specific gravity of the material of construction is too high.

Now, with Titanium, the design engineer can capture the strength of alloy steel at barely more than half the weight. What's more, Titanium is unaffected by most corrosives . . . and is impervious to the deadly attack of sea water and marine atmospheres. Its coefficient of expansion is low . . . and it can withstand long-time operating temperatures as high as 1000°F.

All types of Titanium mill products, from foil to seamless tubing, are made by TMCA. With production going up and prices going down, now is a good time to design with Titanium. Technical literature on Titanium is available just by asking.

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TITANIUM METALS CORPORATION OF AMERICA, 233 Broadway, New York 7, N.Y.

Yield Point . . .

at room temperature but is appreciable at -196° C. (-320° F.). The elastic limit and yield strength are also much higher at -196° C. than at room temperature and the stress separation between the various yield criteria is much greater. At both temperatures the elastic limit and the yield strength increase with decreased ferrite grain size, approximately as the reciprocal of square root of the grain diameter, although there is some deviation in this rule for large grain sizes. The micro-strain and the micro-creep are affected very little by grain size but depend rather strongly on austenitizing temperature, cooling rate and steel chemistry.

The authors discuss their results in a qualitative way in terms of the Clark-Wood dislocation model for yielding which is very similar in many details to the Stroh - Petch model of brittle fracture. In both models dislocation groups are visualized as piling up at grain boundaries, or other barriers, until the local stresses are built up sufficiently to cause yield (Clark-Wood) or a micro-crack (Stroh-Petch) in the adjoining grain and cause either gross yielding or fracture. The data in general agree with the Clark-Wood model except for the large amounts of micro-creep observed at low temperatures, which is not readily predicted. However, it would probably require only a minor modification of the theory to account for the appreciable micro-creep.

In one of the very interesting tests mentioned, fracture occurred during, or subsequent to, micro yielding below the static yield point. This was not discussed. It would be very interesting to see additional delay time studies on fracture. In a recent paper E. T. Wessel observed pre-yielding as a function of temperature and found a distinct maximum in the pre-yield strain. He postulates that there is a temperature below which piled-up dislocation groups initiate microcracks as well as gross yielding and above which only yielding occurs. Unfortunately the authors of the present paper studied delayed yielding only at -196° C. (-320° F.) and room temperature. It would be extremely interesting to see results of similar tests at intermediate temperatures.

The yield phenomenon in mild steel is certainly complex and simple theories such as the widely accepted Cottrell-Bilby cannot be correct in detail. From work such as this, however, a better understanding of the phenomenon is being obtained.

J. H. Bechtold

New Uses for Carburized Steels

Review of "Fatigue Durability of Carburized Steel", by seven authorities. 123 pages. Published August 1957 by American Society for Metals.

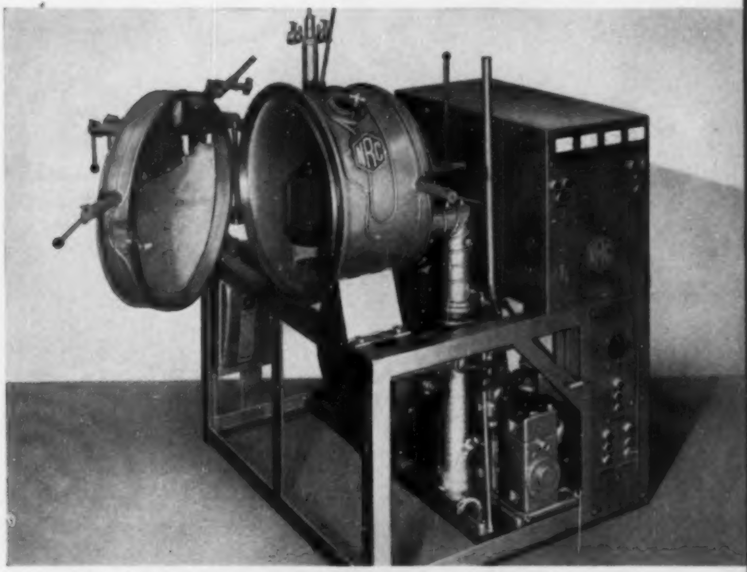
As a result of the growth in use of mild steels with carburized surfaces during recent years, we have, in effect, access to a new group of engineering materials. As is often the situation with new materials, there is a need for data to govern applications of these materials. As to carburized steels, for example, comparatively little is known about their fatigue characteristics and the interrelationship of several factors having an important effect on fatigue properties.

Some new light on the subject is

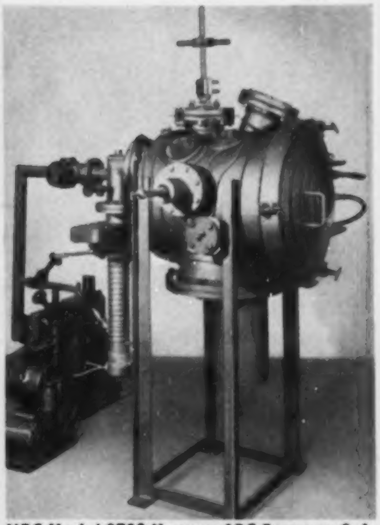
(*Continued on p.* 218)

Get Started Easily In Vacuum Metallurgy

NRC experience and standard ARC, INDUCTION and RESISTANCE furnaces can remove the mystery from vacuum metallurgy



NRC Model 2551 Vacuum INDUCTION Furnace. Packaged facility for melting, purifying, alloying, casting and heat treating. Capacity 12 lbs. Other standard and special induction furnaces with capacities up to 5000 lbs.



NRC Model 2703 Vacuum ARC Furnace. Safe and versatile unit for consumable or nonconsumable electrode melting into cold mold or skull (consumable head not shown). Other arc furnaces with capacities to 10,000 lbs.

NRC Model 2904-B Vacuum RESISTANCE Furnace. Over 100 now in use for melting, purifying, alloying, casting, sintering, brazing, annealing, and heat treating. Capacity 2-8 lbs. Temperature above 2000°C. Pressures to 10^{-5} mm Hg. Other standard resistance bell, muffle, and pit furnaces with hot zones to 54" dia. by 12'.

If you're considering vacuum metallurgy as part of your product improvement or quality control program, you don't have to start from scratch. You can get a head-start by drawing on the experience NRC has gained from building and operating more high vacuum furnaces than any other organization in the world. You can easily find out

If vacuum metallurgy can help you as it has others.

Whether you really need to run your own development program.

What type of furnace would be most suitable for your program.

How to avoid the expensive pitfalls which have so often trapped beginners.

Then, if you decide to run your own development program, you'll find you can get started easily, economically and quickly with a standard NRC furnace, such as those shown here. You won't need a vacuum expert to run it either. NRC furnaces are designed for simplicity, and our engineers will teach you up-to-date operating techniques. This is the way for you to get useful results sooner, with a minimum investment in equipment, time, and operating costs.

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IN THIS

Testing—Inspection—Research... Without exception, each step in these technical and scientific operations in the giant metal industry is governed by ME Factors—by an engineering knowledge of metals. Without exception, each segment of the giant metal industry plans extensive expansion in research and development, in testing and metallurgical controls. The market for technical and scientific equipment, for instrumentation, is big today, will be bigger tomorrow. Metals engineers and metallurgists look to their American Society for Metals, and to their magazine, Metal Progress, to keep abreast of this booming engineering progress. They receive 100 million pages of engineering information annually. They will tell you it is their best buy. They tell us by a renewal rate of 90% each year.

The Production of Metals... In the steel mill, the smelter, the large forge shop, technical management has increased sharply since 1940, is only now on the verge of further tremendous expansion of influence. Metals engineers have the knowledge to put the muscle in the metal. They control and determine melting, heating, and forming operations through the constant use of ME Factors. Metal Progress is the only magazine to attract and deliver the men in the mill whose primary interest and influence is *on the metal*.

Carburized Steels . . .

provided by this book, based on a series of educational lectures prepared by seven members of the General Motors Corp. research staff for presentation at the 38th National Metal Congress. Experts in each of several areas outline the nature of their research, their test methods and their conclusions.

Although the book does not attempt to serve as a complete manual for applications of steels of this type, it provides an effective guide to test methods for determining the suitability of carburized steels for potential applications.

Among the new investigations carried on by the book's authors are those concerning the effect of skin condition on durability, the effect of different types of carburizing atmospheres and the effect of residual stresses on durability. Each of these is studied independently as well as in relationship to each other.

Among information developed by the authors is the knowledge that increases in fatigue life can be obtained by *(a)* electropolishing after carburizing, *(b)* minimizing surface oxidation and *(c)* using low-carbon carburizing steels.

T. H. DuMond

Relationship of Carbide Precipitation to Brittleness in 18-8

Digest of "Carbide Precipitation and Brittleness in Austenitic Stainless Steels", by A. Kramer and W. M. Baldwin, Jr., Preprint No. 32, 1957.

As a general class, austenitic stainless steels show a decrease in ductility when the rate of straining is increased. Although the embrittlement is not marked (ductility decreases by 40% as measured by true strain at fracture), it could be of importance in drastic forming operations.

The authors studied several 18-8 stainless steels of different carbon levels (Types 302, 304, and 304 LC) in the fully annealed and the sensitized condition. Sensitization produced a tendency for embrittlement at low strain rates and low temperatures and had little effect on the drop in ductility at high rates of strain. The embrittlement caused by carbide precipitation was accompanied by intergranular fracture.

Magnetic measurements of the amount of martensite formed during deformation showed no correlation with ductility. This observation is in agreement with earlier results discounting martensite formation as a cause of the high strain rate embrittlement. Similar measurements on the sensitized materials indicate that differences in martensite content are not responsible for the low strain rate embrittlement either.

While offering no mechanism responsible for the embrittlement, this work eliminates two frequently suggested causes. In addition, the authors show that sensitization can lead to embrittlement at low temperatures and low strain rates. Clearly more study is required to understand these phenomena.

Ray W. Guard

Utica technician viewing a meltdown of Udimet 500—a new vacuum melted alloy in the high temperature field.

NEW U.S.I. ZIRCONIUM PLATELETS ELIMINATE SAFETY PROBLEM

You're looking at a new form of zirconium—the non-pyrophoric, non-hygroscopic platelets produced by U.S.I.'s new plant at Ashtabula, Ohio. Zirconium platelets eliminate the handling hazards of the more familiar sponge metal because of their low ratio of surface to weight. Special shipping precautions are not required. Platelets also make possible a safer, cleaner melting operation.

Production of U.S.I. zirconium employs a new, semi-continuous sodium reduction process, yielding top-quality metal almost completely free of sodium, magnesium, chlorides, hydrogen and moisture. Prices are coming down too, and these will be reflected in lowered costs of fabricated parts. Zirconium equipment is expected to be available in the not too distant future for about twice the cost of stainless steel, depending upon the complexity of the part.

The new U.S.I. production facilities will make available an important new source of zirconium for both government and industrial use. By next year, a million pounds will be available for industry from U.S.I.'s new plant, over and above the million pounds per year committed to the A.E.C. Thus, a reliable source of high-quality zirconium will be available to the nuclear industry and to manufacturers of chemical processing equipment.

For further information write for the new booklet, "Zirconium and Hafnium". For detailed information and assistance on your particular problem, call Bill Greenleaf, Manager of Metals Development.

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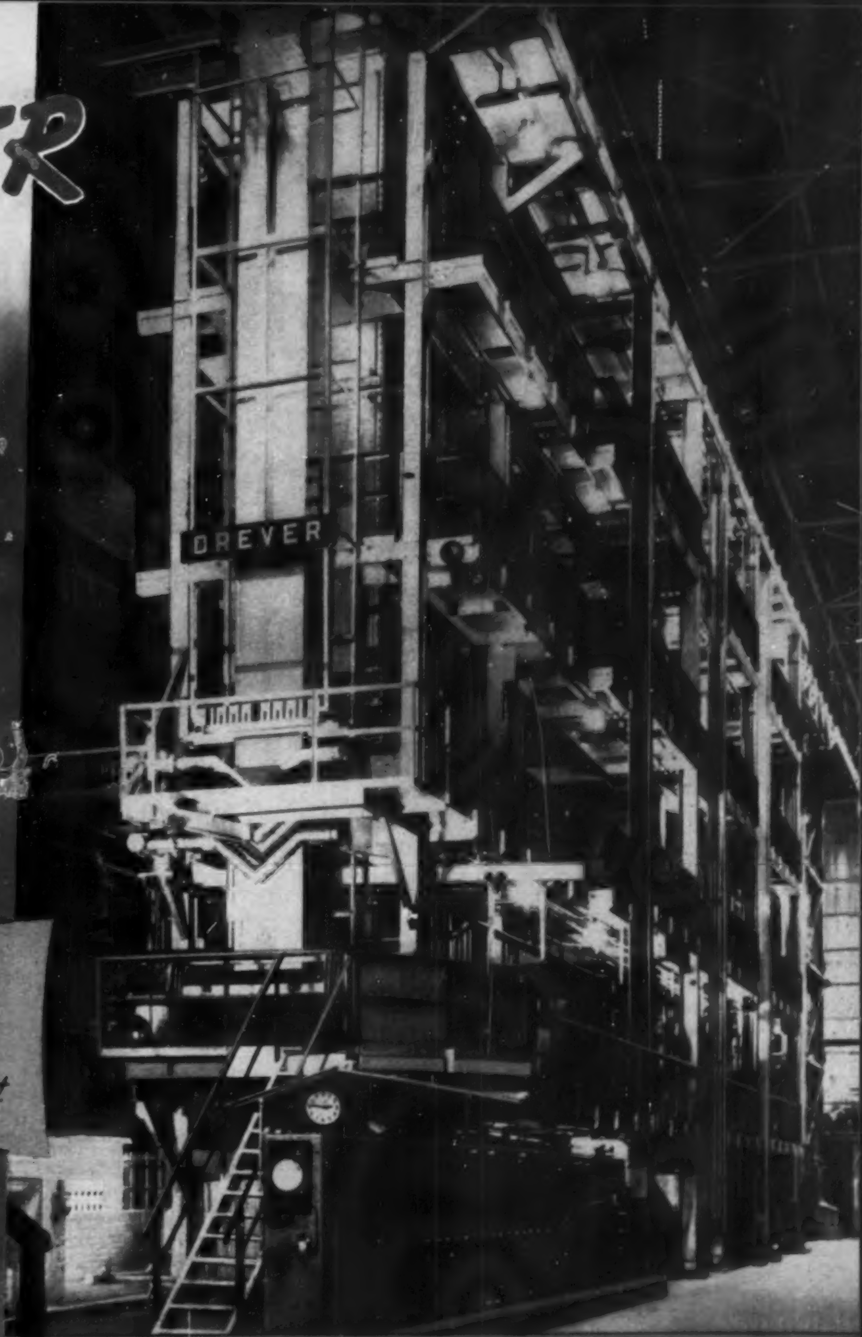
STRIP ANNEALING FURNACE LINE



Delivery end of furnace for low carbon tin plate strip installed in a large Canadian steel plant

This furnace has an installed electrical input in heating and soaking zones of 3000 KW for a rated production of 37,000 lbs/hour on .0099" x 33" wide strip running at 550 FPM.

Furnace equipment is designed to handle strip in thicknesses from .0075" to .020" in widths varying from 19" to 38".

HNX atmosphere gas is used to purge the furnace.

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is facilitated by the production of high-grade ores, the maintenance of a fine ore vessel transportation fleet, modern mining equipment, and the employment of skilled employees. This "team work" keeps industry and commerce ahead of the times, thus insuring further development on a greater scale than ever before in history.

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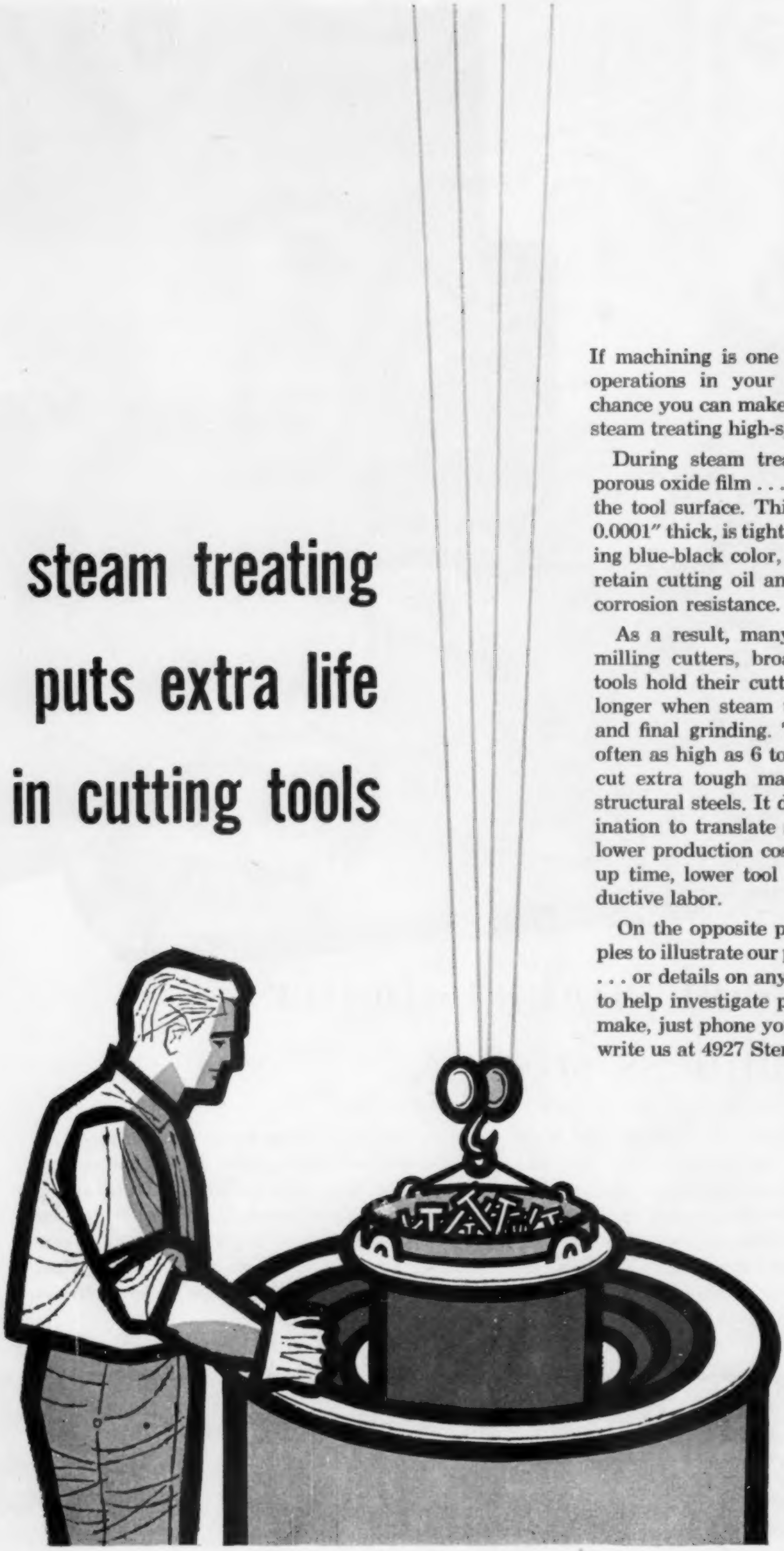
IRON ORE ★ ALLOYS ★ VESSEL TRANSPORTATION ★ COAL

The Cleveland-Cliffs Iron Company

UNION COMMERCE BUILDING • CLEVELAND 14, OHIO

steam treating puts extra life in cutting tools



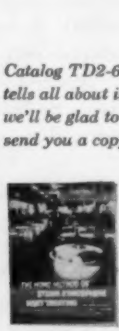
If machining is one of the more expensive operations in your plant, there's a good chance you can make spectacular savings by steam treating high-speed steel cutting tools.

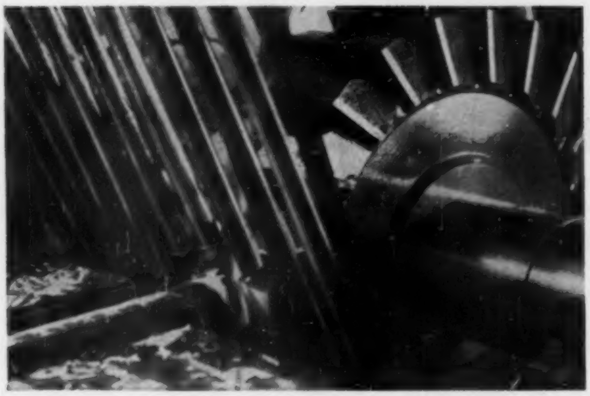
During steam treatment a tough, hard, porous oxide film . . . Fe_3O_4 . . . is formed on the tool surface. This micro-thin film, only 0.0001″ thick, is tightly adherent, has a pleasing blue-black color, is sufficiently porous to retain cutting oil and has a high degree of corrosion resistance.

As a result, many drills, reamers, hobs, milling cutters, broaches, saws, and other tools hold their cutting edges 5% to 100% longer when steam treated after tempering and final grinding. This ratio goes up . . . often as high as 6 to 1 . . . for tools used to cut extra tough materials such as alloyed structural steels. It doesn't take much imagination to translate such extra tool-life into lower production costs through reduced set-up time, lower tool costs and less non-productive labor.

On the opposite page are just four examples to illustrate our point. If you want others . . . or details on any of these . . . or want us to help investigate possible savings you can make, just phone your nearest L&N office or write us at 4927 Stenton Ave., Phila. 44, Pa.

Catalog TD2-620(1) tells all about it too; we'll be glad to send you a copy.





Milling Cutters Do 500% More Work . . . When milling the ends of these Nichrome heater rods operators always averaged 25 cuts . . . then spent 20 to 30 minutes changing to a new cutter. In an effort to reduce such high job time, steam treated tools were made standard practice in this shop. The results: operators averaged 150 cuts before resharpening was necessary . . . 500% more use from each tool . . . 1½ hours less set-up time for every 150 pieces.

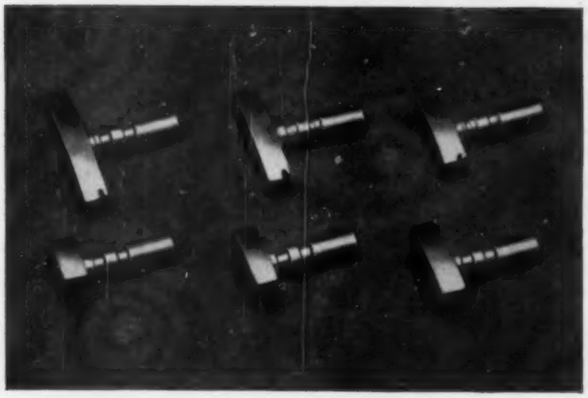
Chipping Rejects Are Eliminated . . . Drilling, reaming and boring these bakelite insulating blocks used to be an expensive job. Although the actual operation didn't take long, the abrasive action of the bakelite dulled tools so rapidly that cracking and chipping caused a prohibitively high number of rejects. The cost of the material and the large number of man-hours invested prior to the drilling operations made the problem even more acute.

To break the bottleneck, steam treated tools were tried. Previously, one tool was good for about 10 holes, with an average reject rate of one out of four blocks. With steam treated tools, the average went up to 25 holes and rejects were no longer a critical factor.

Drill Maker Improves Product Quality . . . The manufacturer of these drills made extensive tests before adopting the steam Homo method as standard treatment for all milled flute regular and heavy duty drills. Here are comparative test results on a 37/64" H.S. drill cutting a 2" billet of S.A.E. 3240 chrome-nickel steel with a Brinell hardness of 248-255 at a speed of 345 RPM, feeding 52 FPM at .007"/rev.

Treatment	Drill No.	1st Test	2nd Test	3rd Test
None	1	33 holes	43 holes	38 holes dull
None	2	31 holes	43 holes	60 holes still cutting*
Steam treated	3	62 holes	64 holes	60 holes still cutting*
Steam treated	4	50 holes	69 holes	60 holes still cutting

*Drill #2 was steam treated before this test. Drill #3 was given an additional steam treatment before this test.



Pick-up From Soft Metal Eliminated . . . A production bottleneck was created when a batch of formed nickel stock, used to make these segments of multipoint switches, came through too soft. Pick-up on the form tool of the automatic screw machine kept ruining the parts.

When experiments with different tool steels and sharpening methods completely failed to solve the problem, a steam treated tool was tried. This one tool finished the entire run of 3000 pieces and was still in good condition. Production delays because of material variations are no longer a problem in this shop.

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Special Reports
On Finishing Non-Ferrous Metals

NUMBER II—Paint Base, Corrosion-Resistant Finishing with Iridite

WHAT IS IRIDITE?®

Briefly, Iridite is the tradename for a specialized line of chromate conversion finishes. They are generally applied by dip, some by brush or spray, at or near room temperature, with automatic equipment or manual finishing facilities. During application, a chemical reaction occurs that produces a thin (.00002" max.) gel-like, complex chromate film of a non-porous nature on the surface of the metal. This film is an integral part of the metal itself, thus cannot flake, chip or peel. No special equipment, exhaust systems or specially trained personnel are required.

Chromate conversion coatings are well known and accepted throughout industry as an economical means of providing corrosion protection, a good paint base and decorative finishes for non-ferrous metals. However, continued developments have been so rapid and widespread that many manufacturers may not be completely aware of the breadth of application of this type of finish. Hence, this digest of current information; to bring you up to date on the many ways in which you can obtain proper surface preparation for painting and increase product durability with a single multi-purpose chemical pretreatment. Report I on decorative, corrosion-resistant finishes and Report III on chemically polished, corrosion-resistant finishes are available on request.

First, it is an accepted fact that metal surfaces should be prepared before painting to make possible an efficient paint system. Naturally, this preparation should provide for good initial paint adhesion. Chemical treatments have proved extremely effective in this respect, particularly those of a neutral or preferably acid nature. Further, to be most efficient, chemical treatments should provide a non-porous barrier to maintain adhesion by sealing the metal from the paint and moisture. They should also provide a self-healing film which prevents lateral corrosion in the event that bare metal is exposed through scratching.

The Iridite chromate conversion coatings meet all these requirements. Iridite is a chemical conversion treatment for surface preparation. It provides initial paint bonding by molecular adhesion. It is acid in nature and produces a film that is gel-like and non-porous in structure. Thus, the Iridite film effectively seals the metal from the paint and from moisture penetration. Because the film contains certain relatively soluble constituents, it will protect areas scratched through to bare metal and prevent lateral corrosion. This is accomplished by a gradual leaching of these constituents into the damaged area.

Further, because of its gel-like, non-crystalline nature, the Iridite film will not affect the appearance or texture of the paint film, nor will it dust or powder to mar the painted surface. Because the film is non-porous, paint coverage is increased, thus substantial savings in paint costs will be realized. In addition, treated parts may be stored for long periods of time prior to painting without the risk of entrapped moisture causing blistering when painting.

Iridite chromate conversion coatings are widely used with equal ease and success under both baked and air-dried paint systems. While the actual adherence properties of the Iridite film do not increase appreciably with its thickness, corrosion protection does. The protection of the Iridite film is proportionate to its thickness and should be taken into consideration when selecting the Iridite to meet your needs. However, it is sometimes necessary to sacrifice maximum corrosion protection for appearance when a finished part is to be only partially painted. For example, it may be desirable to use a thin, clear, bright Iridite film if the unpainted areas must present a chrome-like appearance. A typical case is that of instrument housings on which the exterior is painted and the inside left unpainted.

On the other hand, if all surfaces of the product are to be painted and maximum corrosion protection is required, the heavier and most protective Iridite films should be used. For example, all surfaces of zinc die cast fruit juicers are finished with a highly protective Iridite film prior to painting to provide maximum resistance to the corrosive action of fruit juices.

Iridite finishes are now available for all commercial forms of the more commonly used non-ferrous metals, including zinc, cadmium, aluminum, magnesium, silver, copper, brass and bronze. In addition to providing an excellent base for paint, the Iridite films also have high decorative value when used as final finishes in themselves.

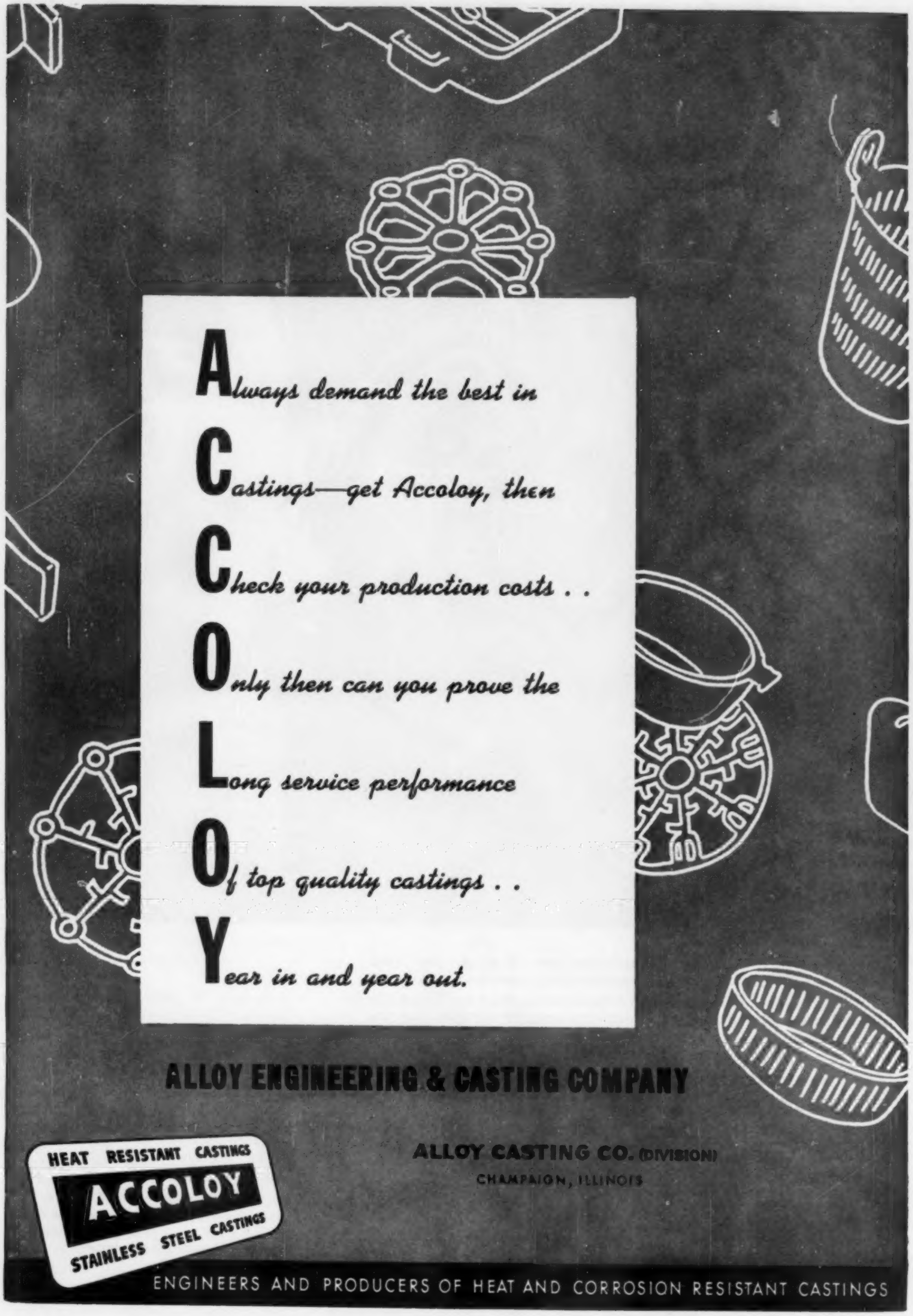
These films can produce a wide variety of pleasing appearances including clear bright, iridescent yellow, bronze, olive drab and brown. In addition, many films can be modified by bleaching or by dyeing. Among the dye colors available are various shades of red, yellow, green, blue or black.

In planning or designing, you should consider the many other characteristics of Iridite finishes which may enter into the specific problem. In addition to their functions as protective and decorative finishes, and as bases for organic finishes and bonding compounds, Iridites have low electrical resistance. Some can be soldered and welded. The film does not affect the dimensional stability of close tolerance parts.

Iridites are widely approved under both Armed Services and industrial specifications because of performance, low cost and savings of materials and equipment.

You can see then, that with the many factors to be considered, selection of the Iridite best suited to your product requires the services of a specialist. That's why Allied maintains a staff of competent Field Engineers—to help you select the Iridite to make your installation most efficient in improving the quality of your product. You'll find your Allied Field Engineer listed under "Plating Supplies" in your classified telephone book. Or, write direct and tell us your problem. Complete literature and data, as well as sample part processing, is available. Allied Research Products, Inc., 4004-06 East Monument Street, Baltimore 5, Maryland.


THE SECRET OF A
STAINLESS REPUTATION


Always demand the best in
Castings—get Accoloy, then
Check your production costs . .
Only then can you prove the
Long service performance
Of top quality castings . .
Year in and year out.
ALLOY ENGINEERING & CASTING COMPANY
HEAT RESISTANT CASTINGS
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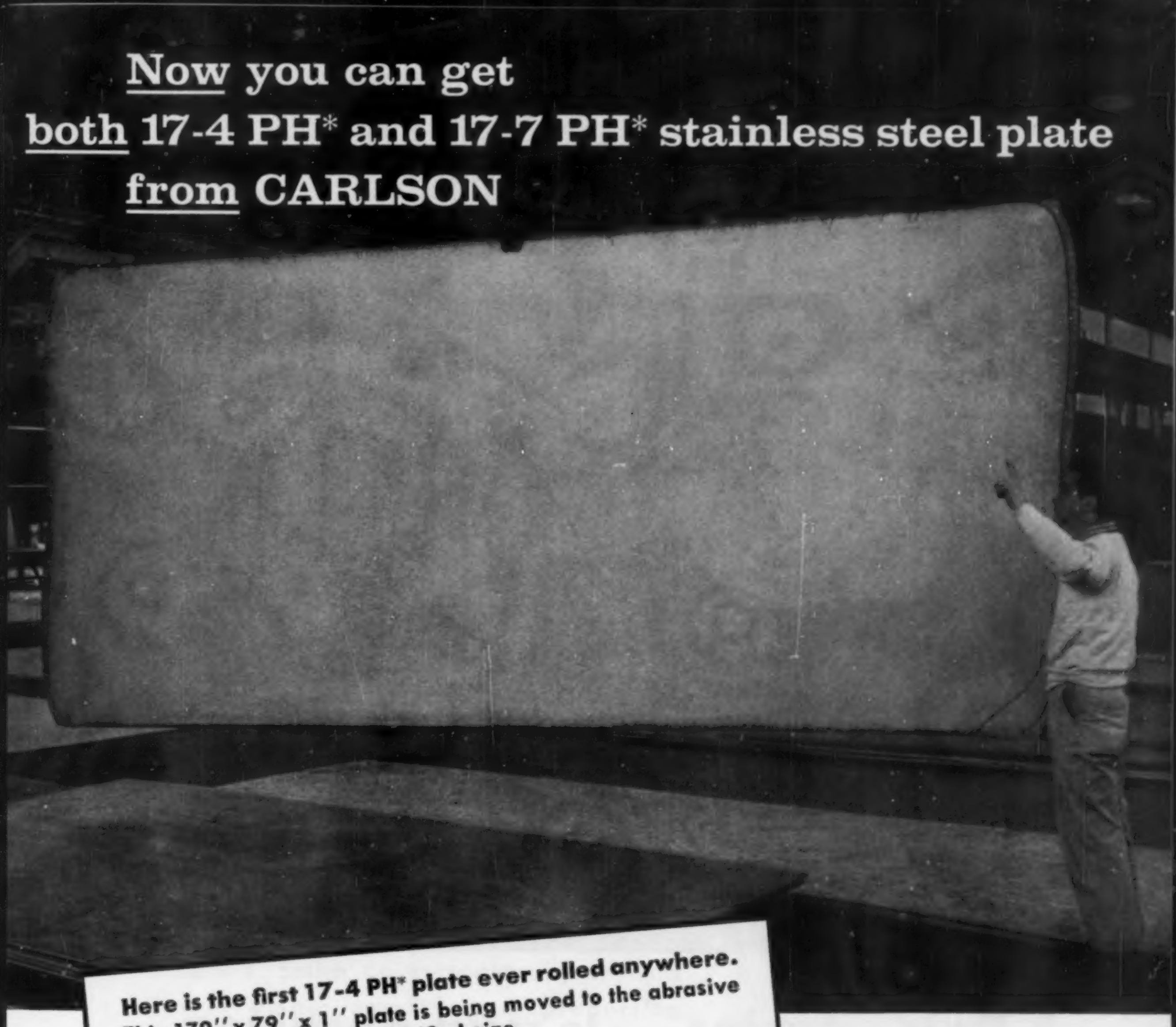
ENGINEERS AND PRODUCERS OF HEAT AND CORROSION RESISTANT CASTINGS



You can build equipment with either of two precipitation-hardening stainless plate grades—17-4 PH* and 17-7 PH*. Both are available at Carlson—both can be cut to your exact specifications to save delays and true-up time in your own plant.

The Armco-developed 17-4 PH and 17-7 PH grades combine ease of fabrication, hardenability, high strength and corrosion resistance. These grades have the desirable mechanical properties of the hardenable chromium types and a workability and corrosion resistance approaching regular 18-8 stainless steels. Simplified low temperature heat treatments will produce a Rockwell hardness of C40 to C50. And tensile strengths range from 180,000 to 215,000 psi depending upon the heat treatment.

Take full advantage of our complete service in stainless steel plate and plate products. Write, wire or phone for detailed information on 17-4 PH and 17-7 PH stainless steels.

*Trade Mark of the ARMCO STEEL CORPORATION

G.O.CARLSON Inc.

Stainless Steels Exclusively

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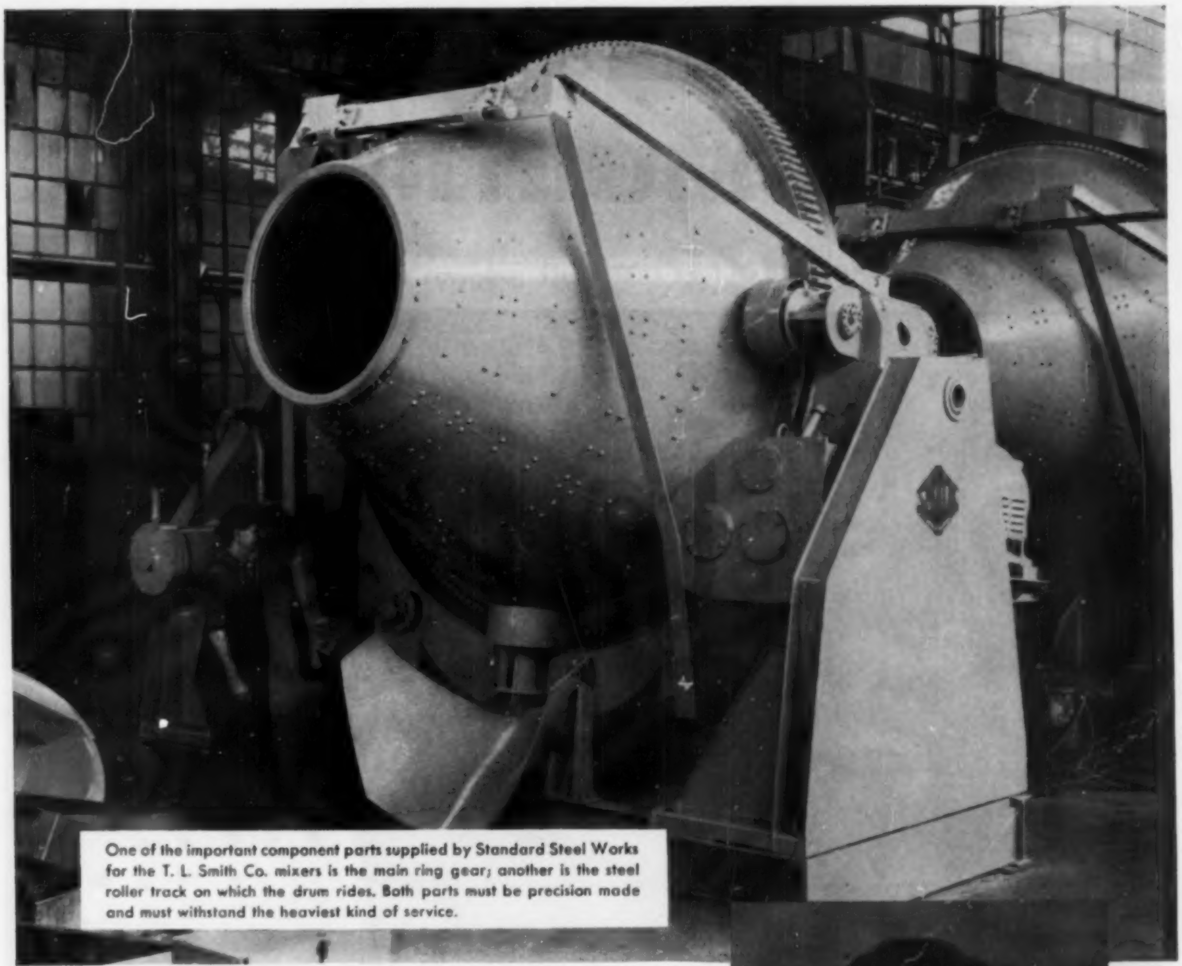
PLATES • PLATE PRODUCTS • HEADS • RINGS • CIRCLES • FLANGES • FORGINGS • BARS and SHEETS (No. 1 Finish)


MILLIONS OF SHARP, SUPERHEATED PARTICLES, traveling at high velocities, quickly wear dust collector linings, mains, downcomers, etc. Metals and most ceramics simply can't withstand this harsh abrasion. But CARBOFRAX refractories can—even at temperatures as high as 2500°F. A CARBOFRAX dust collector lining in an ore sintering machine is, for example, still in use after 10 years' service.



One of the important component parts supplied by Standard Steel Works for the T. L. Smith Co. mixers is the main ring gear; another is the steel roller track on which the drum rides. Both parts must be precision made and must withstand the heaviest kind of service.

"The T. L. Smith Co. is constantly seeking design improvements and production economies. Standard Steel Works has proved a big help to us in both respects."

As suppliers of component parts to the T. L. Smith Co.—world's oldest and largest manufacturer of concrete mixers—we have made it *our* business to get to know *their* business well enough to consider ourselves a part of their team.

It is our policy to work in the closest possible cooperation with all of our customers to assure maximum quality at lowest possible cost. Let us discuss your casting and forging needs with you. You'll find that service to our customers is as important as the quality of the products we make. Write Dept. 3-L.

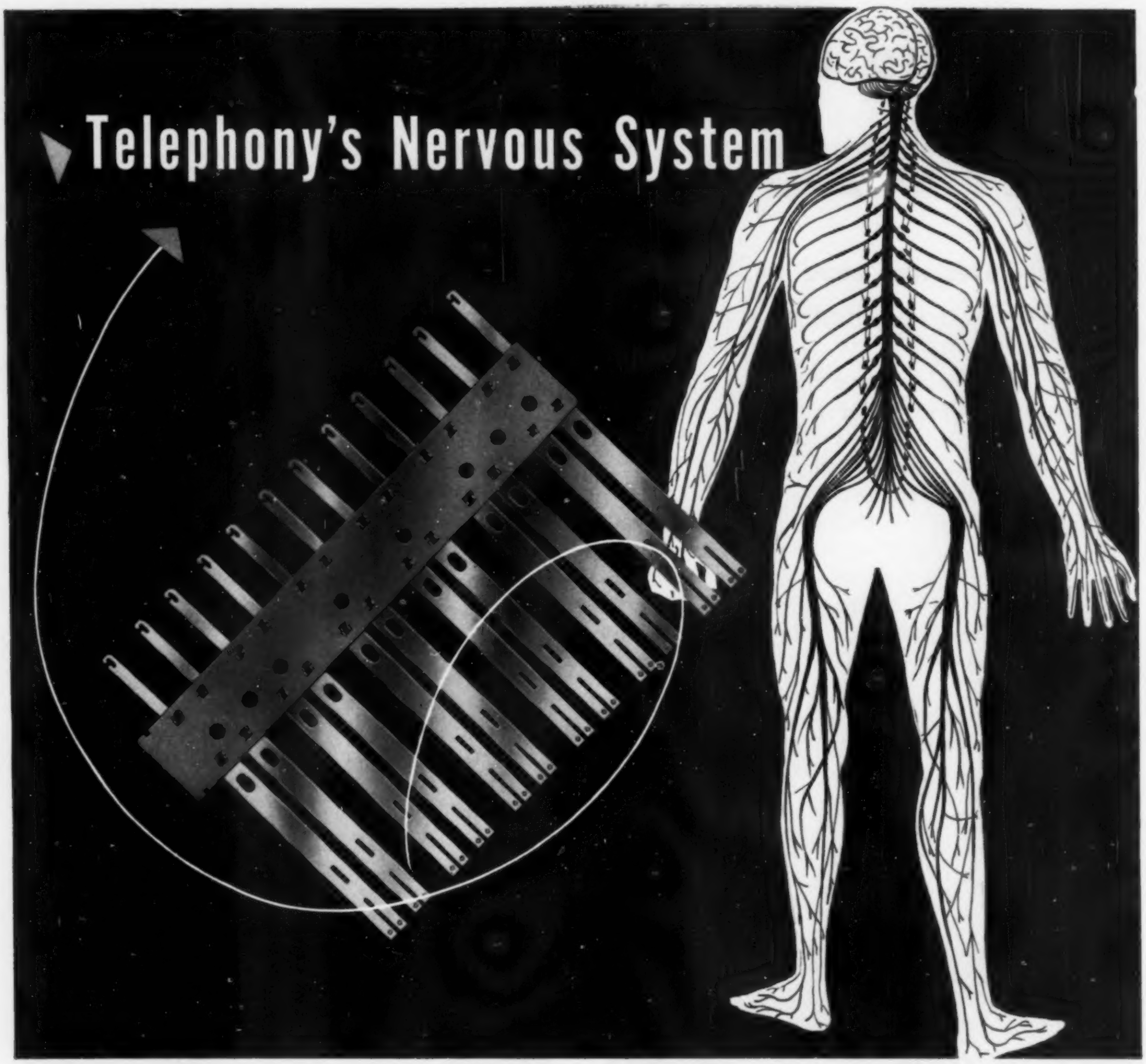
"We are particularly impressed with Standard's methods-people and the way their engineers so effectively supplement our own in constantly suggesting design improvements and production economies," says R. R. Kupfer, purchasing agent for the T. L. Smith Co., Milwaukee, Wis.

Standard Steel Works Division

BALDWIN · LIMA · HAMILTON

BURNHAM, PENNSYLVANIA

Rings • Shafts • Car wheels • Gear blanks • Flanges • Special shapes



. . . relies on "neurons" of Seymour Nickel Silver

Dial telephones carry your voice to the ends of the earth through an intricate electrical network which closely resembles the human nervous system. Seymour nickel silver plays a key role in modern communications as part of the North Electric Company "Crossbar Switching System" which automates independent telephone company exchanges.

Tiny, neuron-like contacts on North Crossbar switch assemblies rely on flat springs of even-tempered Seymour nickel silver for *trillions* of "makes-and-breaks".

Easy to work, corrosion-resistant and possessing excellent conductivity, Seymour nickel silver has an enviable reputation for quality and uniformity among hundreds of manufacturers who say: —

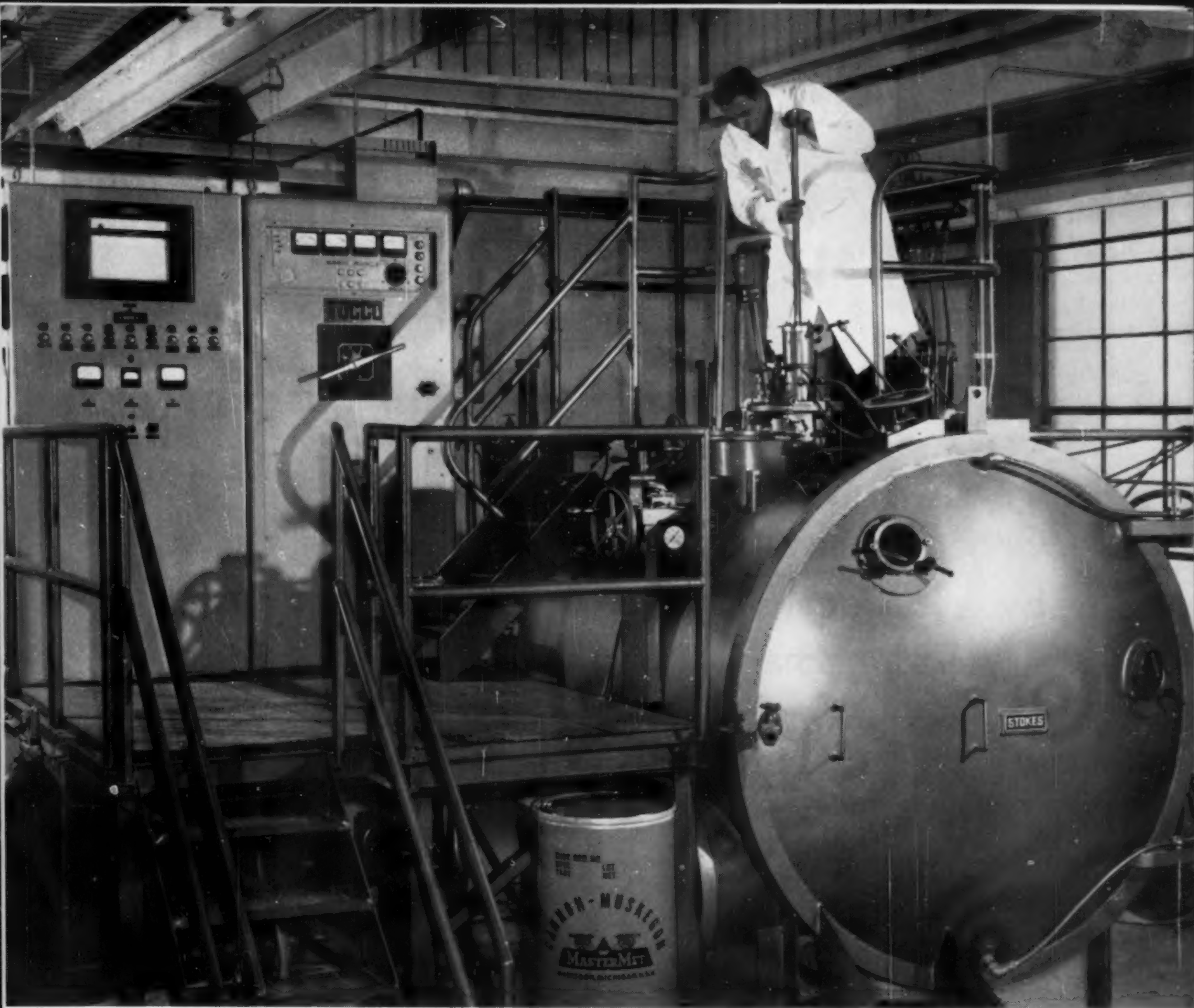
"Specify SEYMOUR. You KNOW it's good!"

Perhaps Seymour metallurgists can help solve your materials problems. Tell us your requirements.

Long distance telephone operators link distant points to the North Crossbar System in Seymour, Indiana.

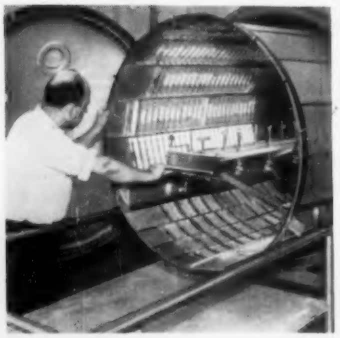
THE SEYMOUR MANUFACTURING COMPANY

21 FRANKLIN STREET, SEYMOUR, CONNECTICUT

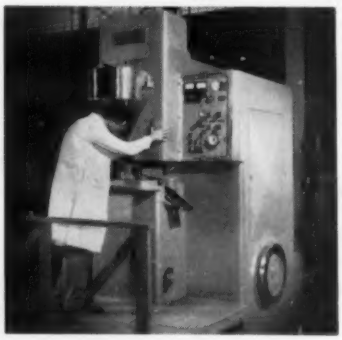


Due to Stokes vacuum lock design, operators can manipulate the melt during the heat without releasing vacuum. Furnace is used for production of special alloys at Cannon-Muskegon Corporation, Muskegon, Mich.

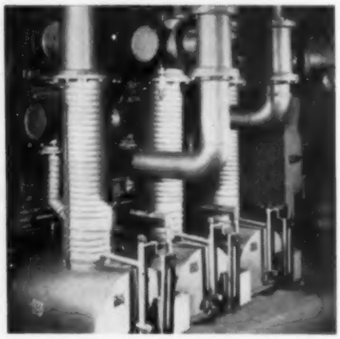
The metals industry is profiting from the use of other STOKES production equipment



Vacuum Metallizers. Stokes offers a complete line of vacuum metallizing equipment to plate metals for improved surface finish . . . also to provide conductive coatings on non-conductive materials.



Powder Metal Presses. Cost savings and the compacting of incompatible alloys have made powder metallurgy an accepted process. Stokes offers the most complete line of presses in the industry.



Vacuum Pumps. For rapid evacuation and holding high vacuums, Stokes offers mechanical pumps, and "Ring-Jet" oil vapor diffusion and booster pumps. New design affords 10 to 100% greater speeds.

Any similarity to a real-life company is purely intentional

Who took the mushrooms out of the switch box?

Maybe it was the size of the prizes on those TV quiz shows. Or Federal expenditures. Something certainly was influencing Watson Volts.

All of a sudden, he began to think in terms of astronomical figures. Told his production people that he wanted a new bumper for their electrical switch box. One that would take 20,000,000 (yep, that's right — twenty million) impacts! And do it without appreciable wear!

Like the hermit who saw a giraffe for the first time, the production manager said, "There ain't no such animal!" Suspecting, of course, that he'd eventually find that there was. Which he did.

Somewhere along the line, A Samaritan told the p.m. about Ampco Metal. About how it is a whole series of uniform-quality copper-base alloys engineered to meet a wide range of special-duty requirements.

Turned out that Ampco Metal was just the ticket. It took 30 impacts a minute — minute after minute, hour after hour, day after day. And it passed inspection without a sign of peening or mushrooming!

More than that, it was available as extruded solid rod in a stock size that closely paralleled requirements. And it took less machining time.

Everything was under control — including costs!

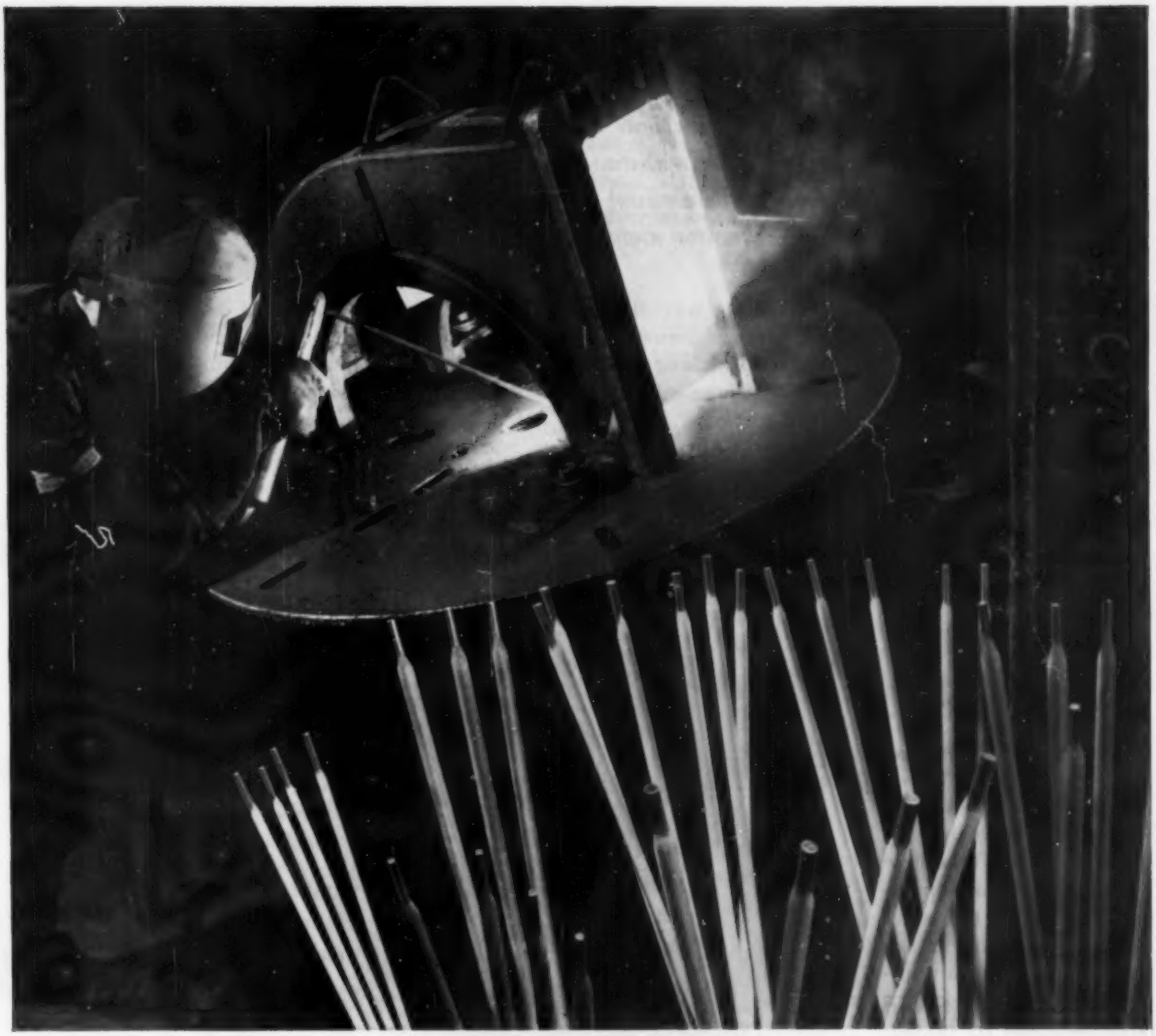
Ampco Metal extruded solid rounds combine high strength and hardness with exceptional resistance to wear, fatigue, and corrosion.

Companies in many fields regularly use extruded solid rods of Ampco Metal — for bearings, bushings, worms, gears, and other vital parts.

Your Ampco stocking distributor can supply diameters from 1/8" to 5 3/8". Call him for prompt service. If you don't know who he is, write us for his name. *Ampco Metal, Inc., Dept. MP-11, Milwaukee 46, Wis. (West Coast Plant: Burbank, Calif.)*

AMPCO® METAL

The metal without an equal



From **Park** Research Laboratories

HOW TO SELECT THE RIGHT METAL CLEANER FOR YOUR JOB

Selection of the right metal cleaner depends upon whether the cleaning is to be done in a power washer or soak tank, and whether electrolytic or emulsion cleaning is to be used. Also to be considered are the parts to be cleaned and whether inorganic or organic matter is to be removed.

While inorganic matter, which includes rust, scale and oxide, may be removed by either mechanical or chemical means, organic impurities—such as oil, grease and drawing compounds—are most effectively removed by chemical reaction.

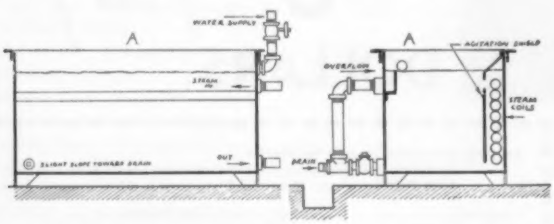
The method most widely used in heat-treating operations, for which Par-Kem Metal Cleaners were primarily formulated, is that which employs a hot-water solution of an alkaline metal cleaner. This method involves three general types of cleaning:

1. **Cleaning in power washers.**
2. **Cleaning in still or agitated tanks.**
3. **Cleaning electrolytically.**

The metal cleaners used for all three types of cleaning are basically the same. They are mixtures of alkalies and alkali salts—principally caustic soda, soda ash, phosphates and silicates—with or without a wetting agent added to improve emulsifying action.

The effectiveness with which the finished mixture performs its primary function of dirt removal depends upon which of these basic materials are used and in what proportions they are combined.

POWER WASHERS—With power washers, in which the cleaning solution is agitated by mechanical action, temperatures of 170-200°F. are recommended for alkaline cleaners, 140-160°F. for emulsion cleaners. In either case, only low concentrations of cleaner are required . . . which makes the power washer not only faster but somewhat more economical than other types.



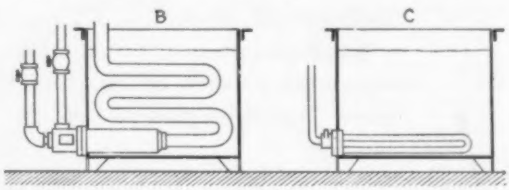
A typical steam-heated tank with overflow and agitation shield. Additional agitation may be obtained with propeller-type agitator, steam jets, or by mechanical or hand agitation of the work.

SOAK TANKS—Soak tanks require a somewhat higher concentration of cleaner than power washers, with temperatures of 180-212°F. With this type of equipment, heat and agitation are essential. The latter is provided by keeping the solution at a rolling boil, by blowing steam through the solution, or by using a mechanical or hand-operated type of agitator.

ELECTROLYTIC CLEANING—In electrolytic tanks, agitation is achieved by the evolution of gases generated by the electrochemical reaction that takes place at temperatures of 160-212°F. This type of cleaning involves three methods: cathodic, anodic, and a combination of the two.

In the first, the work is the cathode. This causes considerable more gassing and therefore better agitation. But is has the disadvantage of plating the work with any metallic impurities that may be present.

When the work is the anode, as in the second method, the danger of plating is eliminated but the surface of the parts is subject to attack. The third method is to clean cathodically first, then switch to anodic cleaning.



Cleaning tanks may also be heated by gas, as in Figure B . . . or by electricity, as in Figure C. Same means of agitation are employed as in the steam-heated tank.

EMULSION CLEANERS—Emulsion cleaners combine high solvency with good emulsifying properties. They are particularly effective in removing heavy deposits of oil, grease, slushing compounds, etc. They also provide temporary protection against rust.

Since emulsion cleaners mix readily with water, petroleum solvents and aromatic solvents, they are suitable for a wide range of metal-cleaning applications and may be used with any type of equipment, including manual cleaning.

PAR-KEM CLEANER CHECK-LIST

Par-Kem Cleaner No. 7, medium duty all-purpose cleaner for use in soak tanks.

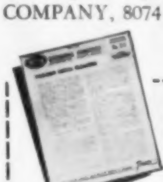
Par-Kem Cleaner No. 9, designed for power washers, also suitable for soak or electrolytic tanks.

Par-Kem Cleaner No. 11, heavy-duty cleaner for use in soak tanks. May also be used in electrolytic tanks.

Par-Kem Cleaner No. 15, an efficient combination of alkalies and synthetic detergents for use in tanks or power washers. Especially suitable for cleaning oily work.

Par-Kem Emulsion Cleaner, for power washers, soak tanks or as a solvent cleaner.

For detailed information on Par-Kem Cleaners and their application, send coupon for Technical Bulletin No. E-1, or write for an analysis of your specific problem to PARK CHEMICAL COMPANY, 8074 Military Ave., Detroit 4, Michigan.



PARK CHEMICAL CO.
8074 Military Ave., Detroit 4, Mich.

Please send your technical bulletin No. E-1 on Par-Kem Metal Cleaners to:

Name__________

Company__________ Position__________

Address__________

City__________ State__________

USS "T-1" Steel reduces weight of lift truck carriage assembly by 66%

INCREASES PAY LOAD PROPORTIONATELY

THE YARDLIFT 350®, manufactured by Ross Carrier Division of Clark Equipment Company, is designed to handle heavy materials on uneven ground. It has a lifting capacity of 35,000 pounds. Many vital strength members of the lifting mechanism are fabricated of USS "T-1" Steel. The reason is elementary: in fork-truck design every extra pound of mechanism forward of the front wheels reduces the machine's load capacity.

According to Clark design computations, the YARDLIFT 350's carriage assembly, if made of structural carbon steel, would have weighed nearly 3 times as much as the "T-1" Steel assembly to obtain the same capacity. And it would have been 3 times bulkier. USS "T-1" Steel, in other words, permitted maximum load capacity at *one-third* the weight and size . . . and increased payload substantially.

The secret is USS "T-1" Steel's 90,000 psi yield point, nearly 3 times that of structural carbon steel. It is this strength that helped make the YARDLIFT 350 possible. And USS "T-1" Steel's high impact resistance and toughness, even at sub-zero temperatures, enable the YARDLIFT 350 to withstand the jolts and jars of rough yard work even in the severest winter weather.

Why don't you take advantage of the unique combination of strength and toughness that USS "T-1" Steel has to offer? It may be the most economical steel you can use. It certainly is at Clark because *many lift trucks now on their drawing boards incorporate USS "T-1" Steel.*

• • •

Our new catalog—USS "T-1"—is complete with technical information and offers many practical suggestions for its use that can save you money. For your free copy, write United States Steel Corporation, Room 2801, 525 William Penn Place, Pittsburgh 30, Pa.

The use of USS "T-1" Steel in the Clark YARDLIFT 350 carriage resulted in vital savings in both weight and space—kept dimensions to a minimum while maintaining lifting capacity of 35,000 pounds.

USS
TRADEMARK

United States Steel Corporation, Pittsburgh • Columbia-Geneva Steel Division, San Francisco • Tennessee Coal & Iron Division, Fairfield, Ala.
United States Steel Supply Division, Warehouse Distributors, Coast-to-Coast • United States Steel Export Company, New York

Remember that we also make USS COR-TEN, USS TRI-TEN and USS MAN-TEN Steels . . . standards for heavy-duty equipment.

USS "T-1" CONSTRUCTIONAL ALLOY STEEL

"USS," "T-1," COR-TEN, MAN-TEN and TRI-TEN are registered trademarks.

UNITED STATES STEEL

STATEMENT OF THE OWNERSHIP, MANAGEMENT, CIRCULATION, ETC.

Required by the Act of Congress of August 24, 1912, as amended by the Acts of March 3, 1933, and July 2, 1946 (Title 39, United States Code, Section 233) showing the ownership, management and circulation of **Metal Progress**, published monthly at Mount Morris, Illinois, for October 1, 1957.

1. The names and addresses of the publisher, editor, managing editor, and business managers are: Publisher, American Society for Metals, 7301 Euclid Ave., Cleveland 3, Ohio; Editor, E. E. Thum, 7301 Euclid Ave., Cleveland 3, Ohio; Managing Editor, M. R. Hyslop, 7301 Euclid Ave., Cleveland 3, Ohio; Business Manager, W. H. Eisenman, 7301 Euclid Ave., Cleveland 3, Ohio.

2. The owner is: (if owned by a corporation, its name and address must be stated and also immediately thereunder the names and addresses of stockholders owning or holding 1 per cent or more of total amount of stock. If not owned by a corporation, the names and addresses of the individual owners must be given. If owned by a partnership or other unincorporated firm, its name and address, as well as that of each individual member, must be given). The American Society for Metals, 7301 Euclid Ave., Cleveland 3, Ohio, which is an educational institution, the officers being: President, Donald S. Clark; Vice President, G. M. Young; Secretary, W. H. Eisenman; Treasurer, C. H. Long; Trustees: A. O. Schaefer, H. A. Wilhelm, G. E. Shubrooks, G. A. Fisher, and Carl E. Swartz.

3. The known bondholders, mortgagees, and other security holders owning or holding 1 per cent or more of total amount of bonds, mortgages, or other securities are: None.

4. Paragraphs 2 and 3 include, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting; also the statements in the two paragraphs show the affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner.

5. The average number of copies of each issue of this publication sold or distributed, through the mails or otherwise, to paid subscribers during the 12 months preceding the date shown above was: (This information is required from daily, weekly, semi-weekly, and tri-weekly newspapers only).

E. E. Thum,
Editor.

(Seal)

Sworn to and subscribed before me this 14th day of October, 1957.

Ray T. Bayless,
Notary Public.

(My commission expires May 19, 1960.)

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